CHEMICAL & ENGINEERING NEWS

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C&EN

AUGUST 17, 1992

LNG SPORTS LARGE-SCALE TECHNOLOGY FOR A GLOBAL OPERATION PAGE 23

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CHEMICAL R&D

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CHEMICAL & ENGINEERING NEWS

C&EN

AUGUST 17, 1992

NEWS OF THE WEEK

- The North American Free Trade Agreement, announced last week by President Bush, is being hailed by the chemical and pharmaceutical industries. **Page 6**
- Drug companies will pay user fees to enable FDA to hire new examiners and speed up drug approval, under a plan winning support from industry and Congress. **Page 6**
- Report by National Science Board panel berates declining state of industrial R&D in the U.S. **Page 7**
- A new study links fluoridation of drinking water to increased incidence of hip fractures in the elderly. **Page 8**
- GAO says FDA should not approve commercial use of genetically engineered bovine growth hormone until questions about its indirect effects on human health are resolved. **Page 8**

COVER: Researcher works on oil additives at Texaco's R&D facility in Beacon, N.Y.

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BUSINESS

New president of Ethyl's chemicals group, E. Gary Cook, is laying out a more market-oriented course for the business' sales, production, and R&D. **Page 15**

GOVERNMENT

EPA plans to appeal a recent court decision rejecting the agency's use of a negligible-risk policy for pesticide residues that remain on foods. **Page 19**

NIH poster session features research conducted by minority students as part of its 20th anniversary celebration of minority research support programs. **Page 20**

Chemical industry praises EPA's proposals to redefine hazardous waste using a concentration-based standard, thus saving firms millions of dollars in waste treatment costs. **Page 20**

SCIENCE/TECHNOLOGY

Global activities in liquid natural gas are characterized by large-scale technology in the design and construction of LNG plants, and although the world market outlook is bright, production and transportation requirements still must be met. **Page 23**

CHEMICAL R&D

Total R&D spending in the U.S. will rise to a new high of $157 billion this year, continuing the pattern of restrained growth that began in 1986, according to C&EN's annual compilation of data on chemical R&D. **Page 38**

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LETTERS

Alcohols for motor fuel

Thank you much Jim Wei for your glorious review of the first two volumes of the "Kirk-Othmer Encyclopedia of Chemical Technology" (C&EN, June 8, page 27) and for your fond anticipation of a half-dozen future articles on topics that interest you. This acknowledgment comes from all who have been, and are, a part of Kirk-Othmer.

One slight nitpick, please! You wrote that "a very important drawback of [alcohols for motor] fuels [is] lower energy per gallon, which translates to a shorter cruise range than gasoline affords before refueling." Not so. At the classic Indianapolis 500, for almost a generation, every race car has used methanol, and pit stops for fuel are anathema.

A personal survey of drivers a few classics back showed that this nuisance was washed out entirely in favor of methanol, because methanol's much greater efficiency allows smaller, lighter engines; lower running temperatures with methanol give greater dependability and longer life to the very expensive engines; and methanol allows much greater safety and many fewer and more easily extinguishable fires during wrecks. (There was a potential record number of wrecks in this year's classic, but no driver was incinerated in fires.) Methanol's oxygen gives less heat of combustion, of course, but it also eliminates knocks and the necessity for lead. Given a chance, drivers of regular cars will agree it is an excellent fuel.

Read on, Dr. Wei. We surely hope that your enthusiasm will continue, it is greatly appreciated.

Donald F. Othmer
Distinguished Professor
Polytechnic University
Brooklyn, N.Y.

A bureaucrat's-eye view

Now the silly season is in full swing, that is, a presidential election year. We bureaucrats hunker down. Your article on EPA contracting (C&EN, July 20, page 18) indicates this silly season may be sillier than usual. We don't mind, many of us. These silly seasons come and go. Things blow over. Nothing changes much. And the amazing thing is that it is all by design. This government will always continue to operate inefficiently. There isn't a lot anyone can do about it, total quality management notwithstanding, short of changing the Constitution. The framers of the Constitution are to blame. They feared a concentration of power and so devised a system of checks and balances. The result: a distribution of power among the branches and an inherently inefficient system. Oh, there have been examples of efficient government—Mussolini, the trains ran on time—but the price is too dear. Our form of government (alas, the republican form, small r, as opposed to democratic, small d, but still one that puts the power of government in the hands of the governed, limited by the Constitution) is the best system in the world. No sarcasm intended. It's the best system the world has ever known. And many countries now have it or something similar. Inefficiency and waste abound.

The silly season brings a lot of bureaucracy bashing. Candidates run against the government. Government is too big. It costs too much. It is inefficient. It's time for a change. Cut spending. Cut taxes. Reduce the deficit.

In this silly season, the Environmental Protection Agency stands apart. Top management there, instead of hunkering down and saying, "Yes yes, we will clean up our act; we will get efficient; we will wisely spend the taxpayers' dollars," has apparently opted for less efficiency. I am astounded, okay not astounded, amused maybe, to hear EPA's Christian Holmes badmouth a cultural mind-set "that views our environmental protection mission as more important than how we manage contracts." Imagine that! Somewhere in the federal government, employees seem focused on their mission and not on the red tape. But if this is amusing, what is really disturbing, dismaying even, is to learn that in Holmes' agency, one out of every 40 employees works for the inspector general. How many federal employees does it take to screw in a light bulb?

The federal bureaucracy is too big and complex for simple solutions. It is complex because of constraints imposed by Congress. (I'm not badmouthing Congress. Congress is functioning just the way the framers of the Constitution intended it to.) Politics requires the executive branch to keep the size of the bureaucracy minimal and accomplish work through contractors whenever possible, "inherent governmental functions" being, of course, excepted. The federal gov-

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Facts & Figures for

CHEMICAL R&D

Mairin B. Brennan and **Janice R. Long,**
C&EN Washington

R&D spending in the U.S. is expected to rise in 1992 to $157 billion, according to estimates by the National Science Foundation. This new high represents a 4% gain over 1991, or slightly more than 1% when adjusted for inflation, and makes 1992 the first year of real growth since 1989.

Viewed in somewhat broader perspective, 1992 continues the pattern of restrained R&D spending that began in 1986. Since then, after adjusting for inflation, overall R&D spending in the U.S. has risen at an annual rate of just over 1%, well below the 5 to 9% annual growth rates of the early 1980s. Thus, although inflation-adjusted R&D spending grew 29% from 1982 to 1986, it rose a much more modest 6% from 1986 to 1992.

As it has since 1981, industry will provide more than half of the total R&D monies this year. Industry, of course, has a vested interest in R&D, which has the potential for industrial applications and commercialization. This year it will contribute 52% ($81.1 billion) of total R&D spending compared with the federal government's 43% ($68.2 billion). But the effect of the federal government on R&D goes beyond funding, because government policies have an impact on industrial support for R&D. Environmental regulations, for example, influence the direction of R&D.

Industry, not surprisingly, is also the leading performer of R&D, accounting for 70% of this work in 1992, down a bit from the 74% of all R&D it performed in the mid-1980s. Universities and colleges, which will perform 12% of R&D in 1992, and the federal government's own laboratories, which will do 11% this year, account for most of the rest. University-based R&D, which has been growing at an annual rate of 10% for the past 10 years, is the fastest growing R&D sector.

In absolute expenditures, the U.S. R&D enterprise dwarfs that of other countries. In 1990, the latest year for which data are available for Japan and the former West Germany (the U.S.'s chief competitors in high-technology areas), the U.S spent more than twice

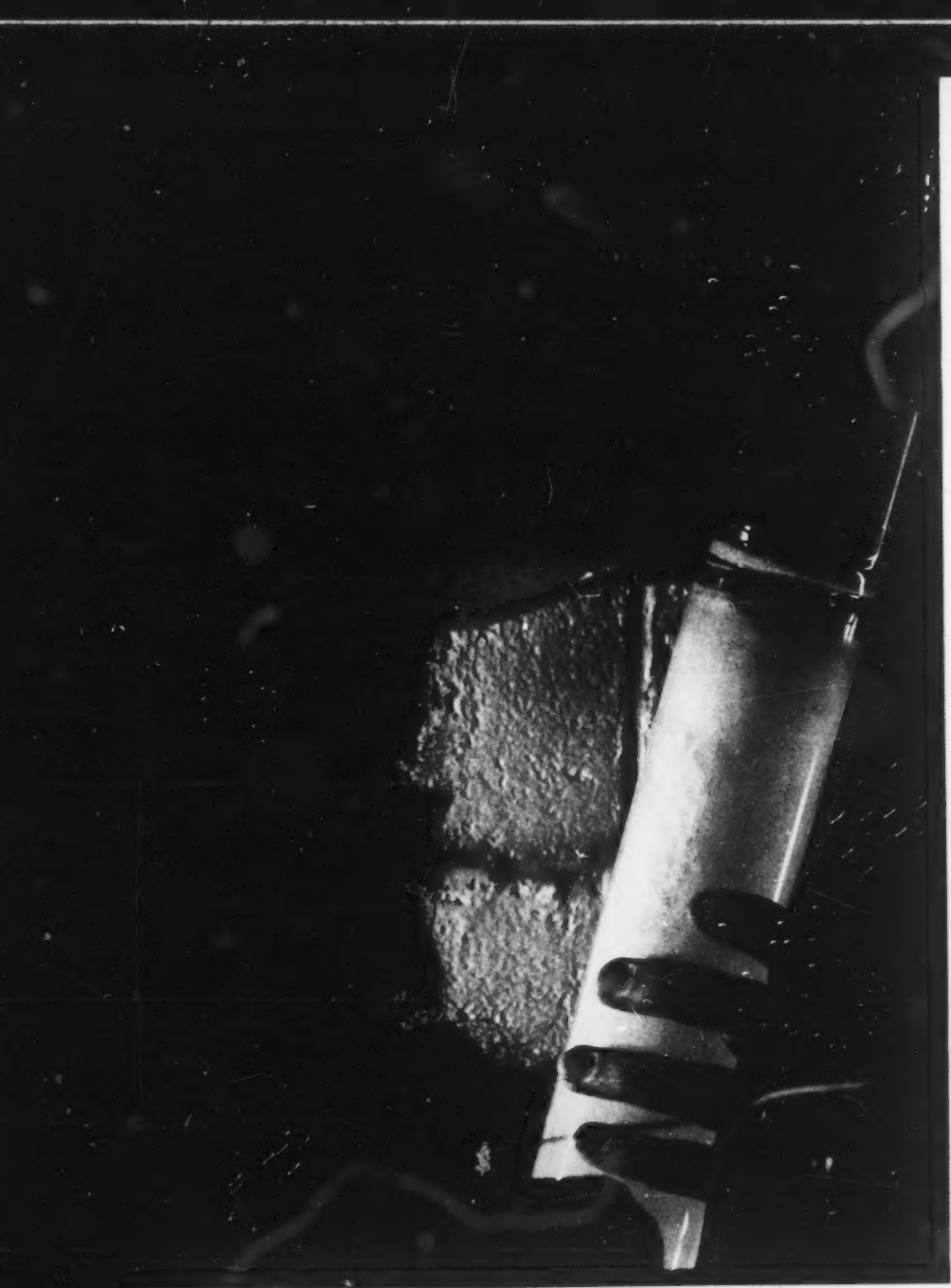
1 OVERVIEW
Who funds R&D and who does the work. Who receives U.S. chemical patents. Fields in which chemical papers are published. **Page 42**

2 FEDERAL GOVERNMENT
Spending on R&D by the government as a whole and by individual federal agencies on all sciences and engineering, but particularly on chemistry and chemical engineering. **Page 48**

3 INDUSTRY
How much industry, especially the chemical industry, spends on R&D. How much U.S. companies spend on R&D abroad. Where industrial scientists and engineers work and how much they are paid. **Page 54**

4 UNIVERSITIES & COLLEGES
Who funds academic R&D and which schools spend the most, particularly for chemistry and chemical engineering. Degrees awarded in chemistry and chemical engineering. Postdoctoral appointments in science and engineering fields. **Page 58**

5 INTERNATIONAL
How R&D efforts in the U.S. compare with those of Japan, the former West Germany, France, Italy, and the U.K. Which countries publish most of the chemical literature. **Page 72**



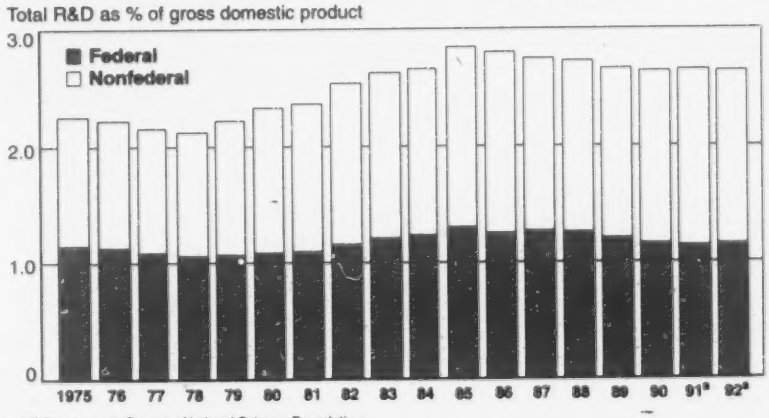
Engelhard photo

The U.S. doesn't compare well with Japan or the former West Germany in R&D spending as a percentage of gross domestic product, either. Share of GDP—the value of all goods and services produced in a country—is a useful measure of the R&D efforts of different countries because it takes into account differences in the economic base for each country. The fraction of GDP spent on R&D in the U.S. declined in the second half of the eighties, dropping from 2.8% in 1985 to 2.7% in 1990. Both Japan and West Germany passed the U.S. by this measure in 1987, so that by 1990, Japan was spending 3.1% and West Germany 2.8% of their GDP on R&D. Moreover, virtually all of Japan's and 95% of West Germany's R&D allotments are designated for nondefense-related R&D. The U.S., however, takes away from civilian research by reserving a much larger chunk (27% in 1990) of R&D money for defense-related R&D. That dropped U.S. support for nondefense-related R&D to 1.9% of GDP in 1990.

as much as Japan on R&D and four-and-a-half times as much as West Germany. But U.S. spending stalled in the late 1980s, remaining at $130 billion in 1990 (constant 1987 dollars), unchanged from the year before and less than 1% higher than in 1988. Japan's inflation-adjusted spending, on the other hand, grew 9% to $59.2 billion and West Germany's grew 2% to $28.8 billion in 1990. Moreover, Japan's spending grew at an annual rate of 7%, after inflation, versus the U.S.'s 4%, for the decade ending in 1990. The U.S. hasn't done any better since 1990, either. According to preliminary data from NSF, U.S. R&D funds fell 1% in real terms in 1991, and are expected to rise only 0.6% above their 1990 level this year.

R&D share of U. S. GDP remains below 1985 peak

Total R&D as % of gross domestic product



a NSF estimates. Source: National Science Foundation

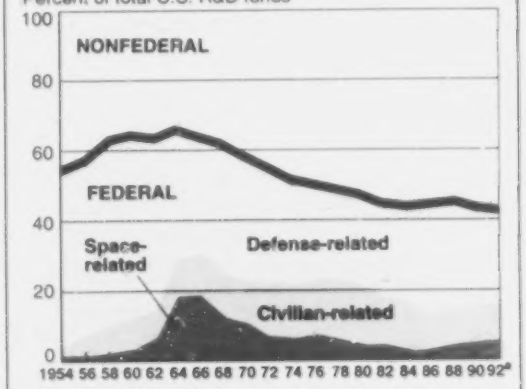
Another way to compare R&D efforts in the U.S. with those in other countries is to look at the number of patents issued. Last year, the U.S. garnered 51% of U.S. chemical patents—14,022 out of a total of 27,433—reversing a seven-year decline. That still leaves 49% of U.S. chemical patents originating abroad. Japan's share, at 21%, and Germany's, at 10%, were unchanged from the year before. Together, these two countries account for nearly a third of U.S. chemical patents.

Growth of industrial R&D in the U.S. trailed inflation in 1991, with funding up just 2% over 1990. Makers of industrial chemicals showed even smaller increases, with their R&D spending up only an estimated 1% over 1990 and far behind their 5% average annual growth rate for the decade ending in 1991. Nevertheless, chemical and allied products companies as a whole, thanks largely to the R&D efforts of the pharmaceutical industry, increased R&D spending to an estimated $13.4 billion in 1991. That's up 7% from 1990, but still lags their 9% average annual growth for the past 10 years. Drug companies, which carry out 46% of the R&D performed by the chemical and allied products industry, boosted R&D spending 9%, also short of their 12% average annual growth rate for the decade.

R&D by U.S. companies abroad in 1990 enjoyed a bonanza year: Spending by chemical and allied products companies increased 33%, more than double their average annual growth rate for the decade. Drug companies, with a 46% hike in their spending, tripled their average annual growth rate for the decade.

In fiscal 1992, which will end Sept. 30, spending by the U.S. government for R&D will rise an estimated 11%, the largest increase in seven years, to $70.4 billion. Among other hikes called for in Congressional appropriations are 14% increases to the R&D budgets for NSF, the Department of Defense, and the Environmental Protection Agency and a 15% increase for the National Aeronautics & Space Administration. Chemistry should gain: EPA could support research on clean fuels or nuclear energy, for example, and DOD could fund research in weapons-related areas such as composites and high-temperature alloys.

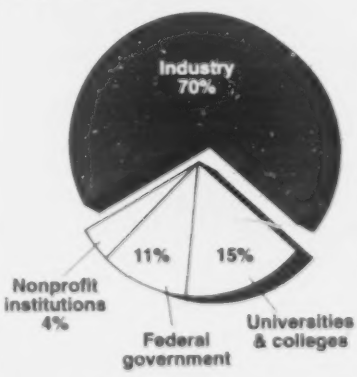
Federal share of U.S. R&D funds has been declining since mid-60s



Note: Total R&D funds for 1992 = $157 billion. a NSF estimate.
Source: National Science Foundation

In fact, NSF estimates the federal government will spend $872 million for research in chemistry in fiscal 1992. This represents an increase of 5% over 1991, a bit better than the 4% average annual growth rate from 1985 to 1992. Five agencies provide nearly 80% of these funds—the Department of Energy, 21%; NSF, 18%; DOD, 15%; Health & Human Services, 15%; and the Department of Agriculture, 9%. Research performed at universities claims $351 million of the federal allotment for chemical research, and just two agencies provide 70% of this funding—NSF (44%) and HHS (26%).

Industry spends 70% of all R&D funds



Total 1992 R&D spending = $157 billion[a]

a NSF estimate. Source: National Science Foundation

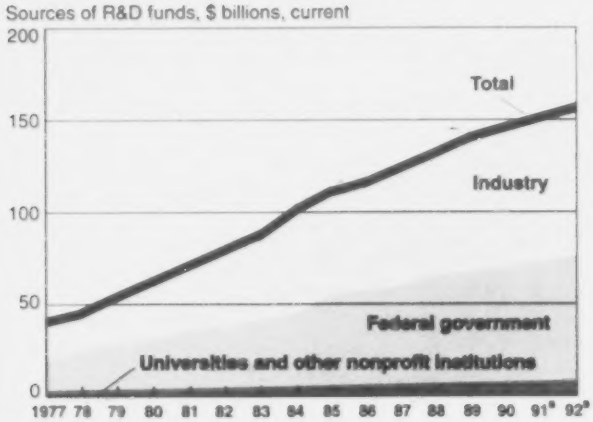
Universities' spending for both research and development in chemistry, even after adjusting for inflation, grew 68% in the period 1980 to 1990. Of the $649 million spent in 1990, 68% came from the federal government. Chemical R&D accounts for only 5% of academic R&D spending in all sciences. But many chemistry-related areas such as biochemistry and molecular biology fall under the umbrella of life sciences, which accounted for 64% of academic spending in the sciences in 1990. Thus, a significant amount of chemical research is probably included here, judging by the distribution of abstracts of papers in *Chemical Abstracts*. For example, the various subdisciplines of biochemistry have accounted for about 40% of all papers abstracted by Chemical Abstracts Service throughout the decade ending in 1991.

Foreign graduate students, whose numbers have been growing at an annual rate of 6% since 1985, represented a fifth of all graduate students in the U.S. in 1990, NSF indicates. But they make up a much larger proportion of graduate students in chemistry (32%) and chemical engineering (42%). The number of bachelor's degrees in chemistry, which has been declining for more than 10 years, was down 29% in 1990 compared with 1980. In chemical engineering, bachelor's degrees surged from 1976 to 1985, then dropped off sharply so that by 1990 it was down 46% compared with 1980. Ph.D. degrees in both fields have generally risen through the decade—up 41% in chemistry and 98% in chemical engineering since 1980. Very likely the increase in foreign graduate students contributes substantially to the increase in Ph.D.s, although some B.S. chemistry graduates, faced with a tight job market, may opt for graduate school. In any case, fewer and fewer U.S. citizens are obtaining B.S. degrees in chemistry or chemical engineering. And, if foreign students are required by U.S. immigration laws to return to their home country after graduating, chemistry and chemical engineering graduates may be in short supply. □

Funding Barely Keeps Pace With Inflation

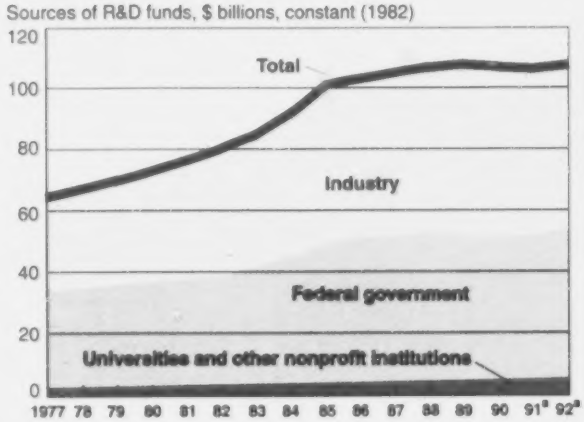
In current dollars, total R&D spending rose 26% in past five years . . .

Sources of R&D funds, $ billions, current



. . . but in real terms that represents a mere 4% increase

Sources of R&D funds, $ billions, constant (1982)



a Preliminary. **Source:** National Science Foundation

SOURCES OF R&D FUNDS: Industry and federal government contribute 95%

$ Billions, current	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	% annual change 1991–92	% annual change 1982–92
Industry	$ 81.1	$ 78.3	$ 75.5	$ 72.1	$ 67.0	$ 62.6	$ 61.1	$ 58.0	$ 52.2	$45.3	$40.7	4%	7%
Federal government	68.2	65.2	63.9	62.6	61.5	57.9	54.3	52.1	45.6	40.8	36.6	5	6
Universities and colleges	5.3	4.8	4.4	3.9	3.5	3.2	2.8	2.4	2.1	1.9	1.7	10	12
Other nonprofit institutions	2.9	2.6	2.3	2.1	1.8	1.6	1.4	1.3	1.2	1.1	1.0	12	11
TOTAL	**$157.4**	**$150.8**	**$146.2**	**$140.8**	**$133.7**	**$125.4**	**$119.5**	**$113.8**	**$101.1**	**$89.1**	**$80.0**	**4%**	**7%**
ANNUAL CHANGE	**4%**	**3%**	**4%**	**5%**	**7%**	**5%**	**5%**	**13%**	**13%**	**11%**	**11%**		
$ Billions, constant 1982													
Industry	$ 56.2	$ 56.0	$ 56.1	$ 55.7	$ 54.0	$ 52.5	$ 52.9	$ 51.5	$ 48.1	$43.5	$40.7	2%	4%
Federal government	47.3	46.7	47.4	48.3	49.6	48.5	47.0	46.3	42.0	39.2	36.6	3	3
Universities and colleges	3.6	3.4	3.3	3.0	2.8	2.7	2.4	2.1	1.9	1.8	1.7	9	8
Other nonprofit institutions	2.0	1.9	1.7	1.6	1.5	1.3	1.2	1.2	1.1	1.1	1.0	5	7
TOTAL	**$109.2**	**$108.0**	**$108.5**	**$108.8**	**$107.8**	**$105.1**	**$103.4**	**$101.1**	**$ 93.1**	**$85.6**	**$80.0**	**1%**	**3%**
ANNUAL CHANGE	**1%**	**−1%**	**0%**	**1%**	**3%**	**2%**	**2%**	**9%**	**9%**	**7%**	**5%**		

Note: Constant-dollar values are calculated by C&EN from NSF data. Totals may not add up because of rounding. a Preliminary figures, NSF estimates. **Source:** National Science Foundation

PERFORMERS OF R&D: Universities' share, though only 12% of total, is rising fastest

$ Billions, current	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	1984	1983	1982	% annual change 1991–92	% annual change 1982–92
Industry	$110.3	$106.8	$104.3	$101.9	$ 97.9	$ 92.2	$ 87.8	$ 84.2	$ 74.8	$65.3	$58.7	3%	7%
Federal government	17.6	16.5	16.0	15.1	14.3	13.4	13.5	12.9	11.6	10.6	9.1	7	7
Universities and colleges	19.0	17.5	16.3	15.0	13.5	12.2	10.9	9.7	8.6	7.9	7.3	9	10
University-associated FFRDCs[b]	5.1	5.0	4.8	4.7	4.5	4.2	3.9	3.5	3.2	2.7	2.5	2	7
Other nonprofit institutions	5.5	5.2	4.7	4.1	3.6	3.4	3.4	3.4	3.0	2.7	2.4	6	9
TOTAL	**$157.4**	**$150.8**	**$146.1**	**$140.8**	**$133.7**	**$125.4**	**$119.5**	**$113.8**	**$101.1**	**$89.1**	**$80.0**	**4%**	**7%**
$ Billions, constant 1982													
Industry	$ 77.8	$ 76.5	$ 77.4	$ 78.7	$ 79.0	$ 77.3	$ 76.0	$ 74.8	$ 68.9	$62.7	$58.7	2%	3%
Federal government	12.4	11.8	11.9	11.7	11.5	11.2	11.6	11.5	10.7	10.2	9.1	5	3
Universities and colleges	13.4	12.5	12.1	11.6	10.9	10.2	9.4	8.6	7.9	7.6	7.3	7	6
University-associated FFRDCs[b]	3.6	3.6	3.6	3.6	3.6	3.5	3.4	3.1	2.9	2.6	2.5	0	4
Other nonprofit institutions	3.8	3.7	3.5	3.2	2.9	2.8	2.9	3.0	2.8	2.6	2.4	3	4
TOTAL	**$111.0**	**$108.0**	**$108.5**	**$108.8**	**$107.8**	**$105.1**	**$103.4**	**$101.1**	**$ 93.1**	**$85.6**	**$80.0**	**3%**	**3%**

Note: Constant dollar values are calculated by C&EN based on NSF data. Totals may not add up because of rounding. a Preliminary figures. NSF estimates. b Federally funded R&D centers. **Source:** National Science Foundation

U.S. CHEMICAL PATENTS: Total gained 6% last year, those of U.S. origin jumped 8%

Number of patents issued	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	Total 1982–91
U.S. origin	**14,022**	**13,028**	**13,795**	**11,245**	**11,395**	**10,505**	**11,533**	**11,504**	**10,553**	**10,614**	**118,194**
to U.S. corporations	12,217	11,240	12,037	9,848	9,900	9,199	10,175	10,119	9,142	9,173	103,050
to U.S. government	335	312	297	259	323	288	321	375	329	311	2,238
to individuals in the U.S.	1,271	1,300	1,299	1,014	1,047	924	986	934	986	1,029	10,790
to foreign-owned corporations in the U.S.	199	176	162	124	125	94	51	76	96	101	1,204
Foreign origin	**13,411**	**12,794**	**13,156**	**10,555**	**10,258**	**9,116**	**9,693**	**8,997**	**8,067**	**8,017**	**104,064**
to U.S.-owned corporations abroad	1,105	1,095	1,134	855	847	757	883	835	701	731	8,943
to foreign corporations	11,387	10,818	11,118	8,946	8,657	7,681	8,083	7,441	6,712	6,517	87,360
to foreign governments	197	153	176	170	200	148	161	166	133	164	1,668
to foreign individuals	722	728	728	584	554	530	566	555	521	605	6,093
TOTAL	**27,433**	**25,822**	**26,951**	**21,800**	**21,653**	**19,621**	**21,226**	**20,501**	**18,620**	**18,631**	**222,258**
% FOREIGN	**48.9%**	**49.5%**	**48.8%**	**48.4%**	**47.4%**	**46.5%**	**45.7%**	**43.8%**	**43.3%**	**43.0%**	**46.8%**

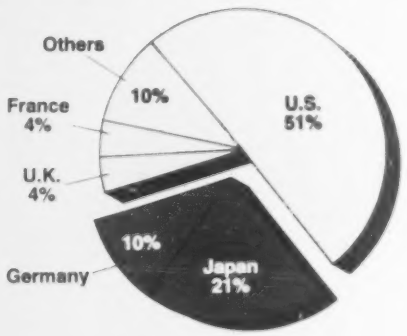
Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. **Source:** U.S. Patent & Trademark Office

RECIPIENTS OF U.S. CHEMICAL PATENTS: U.S.'s share edged up, reversing seven-year decline

% of patents issued	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	Total 1982–91
U.S. origin	**51%**	**50%**	**51%**	**52%**	**53%**	**54%**	**54%**	**56%**	**57%**	**57%**	**53%**
Foreign origin	**49**	**50**	**49**	**48**	**47**	**46**	**46**	**44**	**43**	**43**	**47**
Japan	21	21	20	20	19	19	18	16	15	14	18
Germany[a]	10	10	10	11	10	11	10	10	11	11	10
U.K.	4	4	4	4	4	4	4	4	4	4	4
France	4	4	3	4	4	3	3	3	3	4	4
Switzerland	2	2	2	2	2	2	2	2	2	2	2
Canada	2	2	2	2	1	1	2	1	1	1	2
Italy	2	2	2	1	1	1	1	1	1	1	1
Netherlands	1	1	1	1	1	1	1	1	1	1	1
Sweden	1	1	1	1	1	1	1	1	1	1	1
Belgium	1	1	1	1	1	1	1	1	1	1	1

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. a Patents prior to October 1990 were issued to West Germany. **Source:** U.S. Patent & Trademark Office

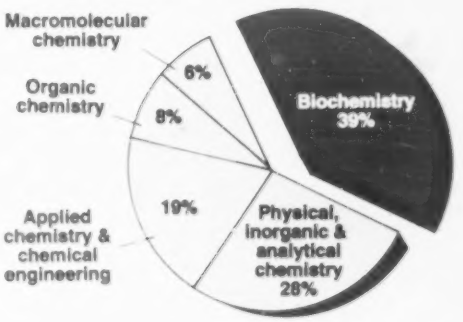
Nearly a third of U.S. chemical patents originate in Germany and Japan



1991 total U.S. chemical patents issued = 27,433

Source: U.S. Patent & Trademark Office

Biochemistry contributes nearly 40% of chemistry papers



1991 total[a] = 453,640

a Number of abstracts of papers published in *Chemical Abstracts*.
Source: Chemical Abstracts Service

PATENT ACTIVITY OF U.S. COMPANIES: Du Pont, Ciba-Geigy, and Dow claim lion's share

Number of patents issued	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	Total 1982–91
CHEMICAL COMPANIES											
Du Pont[a]	651	533	495	437	449	371	396	416	387	331	4,466
Ciba-Geigy	414	409	346	279	286	244	307	290	244	281	3,100
Dow Chemical	332	400	431	421	469	371	336	328	246	277	3,611
Dow Corning	135	122	105	82	58	68	55	52	37	35	749
Union Carbide	131[b]	127[b]	132	141	159	208	242	231	182	202	1,755
Monsanto	129	84	87	76	91	111	100	138	136	131	1,083
W. R. Grace	121	105	111	61	44	43	45	57	52	49	688
Air Products	119	98	119	70	85	61	80	60	49	54	795
Ethyl	118	108	87	51	48	77	105	76	44	31	745
American Cyanamid	106	136	114	101	107	92	115	111	128	129	1,139
Olin	105	74	80	60	58	81	117	112	86	80	853
PPG Industries	93	100	112	118	118	124	128	137	137	177	1,244
Hercules	63	35	47	32	50	43	41	39	37	30	417
Rohm & Haas	49	32	32	18	22	33	31	37	55	49	358
GAF Chemicals	40	42	50	23	15	12	23	19	21	32	277
International Flavors & Fragrances	38	40	31	24	38	76	104	95	87	87	620
TOTAL[c]	**2644**	**2445**	**2379**	**1994**	**2097**	**2015**	**2225**	**2198**	**1928**	**1975**	**21,900**
ANNUAL CHANGE	**8%**	**3%**	**19%**	**−5%**	**4%**	**−9%**	**1%**	**14%**	**−2%**	**−19%**	
DRUG COMPANIES											
Merck	152	134	173	125	123	103	105	135	115	135	1,300
Warner-Lambert	120	108	117	113	118	101	73	49	34	25	858
Pfizer	91	82	79	63	67	72	72	89	61	72	748
Abbott Laboratories	79	64	39	39	30	29	36	32	32	50	430
Hoffmann-LaRoche	78	78	93	59	86	84	74	78	90	118	838
Eli Lilly	66	73	75	68	85	82	107	80	74	104	814
American Home Products	46	66	78	69	46	38	49	32	24	43	491
Upjohn	23	26	30	15	26	66	66	109	73	123	557
SmithKline Beckman	13	29	62	56	54	28	43	68	59	66	478
TOTAL[c]	**668**	**660**	**746**	**607**	**635**	**603**	**625**	**672**	**562**	**736**	**6,514**
ANNUAL CHANGE	**1%**	**−12%**	**23%**	**−4%**	**5%**	**−3%**	**−7%**	**20%**	**−24%**	**−29%**	

Note: Includes U.S. chemical and drug companies and U.S. subsidiaries of foreign companies that have received more than 1000 U.S. patents since 1962. a Includes patents issued to Conoco, acquired in 1981, for all years. b Includes patents issued to Union Carbide Chemicals & Plastics, Union Carbide Chemicals & Plastics Technology, and Union Carbide Industrial Gases Technology. c These totals include patents issued to companies in this table only. **Source:** U.S. Patent & Trademark Office

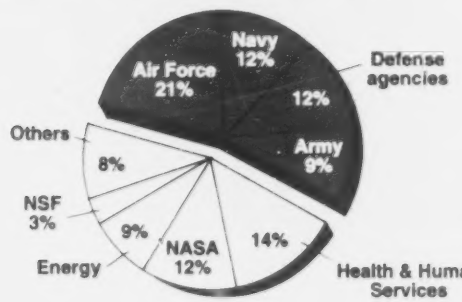
ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS*: Fields' shares changed little in decade

	1991	1990	1989	1988	1987	1986	1985	1984	1981	% change 1981–91
BIOCHEMISTRY	39.5%	36.9%	39.2%	39.7%	40.5%	40.4%	40.5%	40.5%	39.0%	0.5%
% of all biochemistry abstracts										
Mammalian hormones[a]	12.2	11.5	12.0	12.0	12.2	12.5	12.3	12.4	6.8	5.4
Mammalian biochemistry[a]	12.0	10.5	10.7	10.8	11.1	10.8	11.1	11.3	15.6	−3.6
Pharmacology	11.4	11.7	12.6	12.7	12.6	12.2	12.3	11.6	12.4	−1.0
Biochemical genetics[b]	9.0	10.1	7.9	7.6	6.7	6.1	5.2	4.2	—	—
Toxicology	6.9	6.7	7.8	7.9	8.3	7.8	7.9	8.0	8.7	−1.8
Immunochemistry	6.2	6.8	6.3	5.8	5.8	6.1	5.3	4.8	3.4	2.8
Enzymes	5.9	6.1	6.1	6.1	5.4	5.6	5.6	5.8	5.9	0
Biochemical methods	5.2	4.7	5.1	5.1	4.8	5.0	4.9	4.9	5.7	−0.5
Plant biochemistry[a]	5.1	5.1	4.6	5.0	5.3	5.2	5.5	6.2	5.8	−0.7
Microbial biochemistry[a]	4.7	5.4	5.1	4.8	5.1	5.7	5.7	5.2	5.6	−0.9
General biochemistry	4.7	5.2	5.1	5.3	4.6	4.7	4.9	5.3	7.5	−2.8
Others	16.7	16.2	16.7	16.9	18.1	18.3	19.3	20.3	22.6	−5.9
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	28.4%	30.3%	29.0%	28.8%	29.0%	29.8%	29.8%	28.8%	28.0%	0.4%
% of all physical, inorganic, and analytical chemistry abstracts										
Spectra	18.1	16.9	18.1	20.0	20.4	20.0	18.4	18.0	18.0	0.1
Nuclear chemistry	16.3	17.1	19.4	17.8	19.5	19.9	21.8	22.2	21.6	−5.3
Electric phenomena	14.8	13.2	13.9	12.5	10.9	10.8	10.8	10.8	11.0	3.8
General physical chemistry	7.3	7.7	6.9	7.2	7.9	7.0	6.9	6.9	7.2	0.1
Analytical chemistry	6.4	7.9	5.1	5.7	5.9	6.8	6.1	6.3	5.8	0.6
Crystallography and liquid crystals	7.4	7.3	7.8	7.0	7.1	7.0	7.5	7.8	8.9	−1.5
Surface chemistry and colloids	6.3	6.0	5.7	5.8	5.0	4.7	4.9	4.5	4.5	1.8
Others	23.4	23.9	23.1	24.0	23.3	23.8	23.6	23.5	23.0	−0.4
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	18.9%	18.2%	18.1%	18.6%	18.0%	18.2%	18.4%	17.6%	19.1%	−0.2%
% of all applied chemistry and chemical engineering abstracts										
Metals and alloys	21.2	24.5	22.1	21.7	20.6	20.8	20.0	18.9	17.9	3.3
Water, wastes, and pollution	22.2	18.8	17.8	20.4	20.4	21.9	20.2	21.0	24.0	−1.8
Ceramics	9.1	9.4	9.1	6.7	6.3	5.8	5.6	5.1	4.8	4.3
Fossil fuels, derivatives, and related products	8.8	8.0	8.7	8.8	9.6	9.0	10.1	10.1	9.4	−0.6
Unit operations and processes	8.3	9.2	10.3	8.0	9.0	7.1	7.5	7.0	6.4	1.9
Pharmaceuticals and pharmaceutical analysis	7.6	8.2	7.8	7.6	7.8	8.2	8.0	7.0	7.5	0.1
Mineralogical and geological chemistry	10.1	7.8	9.3	11.8	11.2	12.0	12.5	14.6	14.1	−4.0
Others	12.7	14.1	14.9	15.0	15.1	15.2	16.1	16.3	15.9	−3.2
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
ORGANIC CHEMISTRY	7.6%	8.7%	7.8%	7.3%	6.9%	5.9%	6.4%	7.6%	8.7%	−1.1%
% of all organic chemistry abstracts										
Physical organic chemistry	21.3	21.2	25.9	23.0	23.9	27.3	30.6	32.0	37.0	−15.7
Heterocyclic compounds[a]	19.0	17.4	16.1	18.8	19.9	15.0	16.1	15.6	18.2	0.8
Organometallic and organometalloidal compounds	16.6	20.4	18.4	15.7	16.1	18.3	16.2	17.1	8.3	8.3
Carbohydrates	8.5	7.4	6.5	8.1	5.6	7.8	5.7	5.7	5.4	3.1
Amino acids, peptides, and proteins[a]	7.3	6.0	4.5	5.8	4.3	3.9	4.6	4.8	4.2	3.1
Aromatic compounds[a]	6.8	7.1	6.9	7.2	7.7	7.3	6.3	6.3	8.7	−1.9
Biomolecules and their synthetic analogs[b]	5.8	5.9	5.8	6.1	5.8	5.0	4.9	4.4	—	—
Others	14.7	14.6	15.9	15.3	16.7	15.4	15.6	14.1	18.2	−3.5
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—
MACROMOLECULAR CHEMISTRY	5.6%	5.9%	5.9%	5.6%	5.6%	5.7%	4.9%	5.5%	5.2%	0.4%
% of all macromolecular chemistry abstracts										
Synthetic high polymers	39.5	38.6	34.4	34.8	35.2	34.1	34.1	34.0	30.3	9.2
Plastics manufacture and uses	25.8	23.3	25.1	23.7	23.6	23.8	25.3	24.2	26.4	−0.6
Textiles	7.1	6.7	7.2	7.3	8.1	8.8	8.2	7.3	9.9	−2.8
Cellulose, lignin, paper, and other wood products	6.3	7.6	9.2	9.6	8.8	9.8	9.1	9.6	10.1	−3.8
Industrial organic chemicals, leather, fats, and waxes[b]	5.6	8.4	8.1	6.8	5.6	4.6	4.4	4.8	—	—
Synthetic elastomers and natural rubber	5.6	4.8	5.6	6.7	7.2	6.7	6.8	7.3	7.9	−2.3
Coatings, inks, and related products	5.5	5.2	5.6	5.7	5.8	7.2	7.2	7.8	7.5	−2.0
Others	4.6	5.4	4.8	5.4	5.7	5.0	4.9	5.0	7.9	−3.3
TOTAL	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	—

How to read this table: Using biochemistry as an example, in 1991 39.5% of all the papers abstracted by Chemical Abstracts Service are in the various subdisciplines of biochemistry; 12.2% of all abstracts in biochemistry, in turn, are in the subdiscipline of mammalian hormones, and so on. a Definition of section changed in 1982. b New section in 1982. **Source:** Chemical Abstracts Service

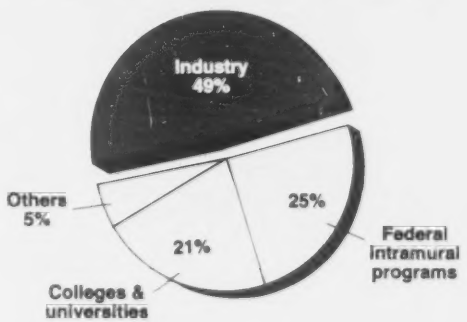
Defense, Civilian Funding Move Toward Parity

Defense Department funds just over half of federal R&D efforts . . .



Estimated fiscal 1992 total federal R&D obligations = $70.4 billion

. . . and just under half of federally funded R&D is performed by industry



Estimated fiscal 1992 total federal R&D obligations = $70.4 billion

Source: National Science Foundation

FEDERAL OBLIGATIONS FOR R&D: Defense programs bounce back

$ Millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Defense	**$38,770**	**$33,966**	**$37,268**	**$37,577**	**$35,415**	**$35,232**	**$32,938**	**$29,792**	**14%**	**5%**
Air Force	15,116	11,900	14,831	15,237	15,034	15,348	13,594	13,261	27	3
Defense agencies	8,481	7,446	6,945	6,859	5,833	5,220	4,767	2,782	14	25
Navy	8,427	8,850	9,586	9,666	9,514	9,508	9,650	9,127	–5	–1
Army	6,458	5,557	5,684	5,659	4,806	5,020	4,809	4,571	16	7
Health & Human Services	**9,781**	**9,246**	**8,406**	**7,903**	**7,158**	**6,606**	**5,658**	**5,451**	**6**	**12**
National Institutes of Health	8,253	7,705	7,137	6,778	6,291	5,851	5,005	4,828	7	11
Alcohol, Drug Abuse & Mental Health Administration	1,022	957	843	696	555	476	396	378	7	22
NASA	**8,543**	**7,435**	**6,533**	**5,394**	**4,330**	**3,787**	**3,420**	**3,327**	**15**	**21**
Energy	**6,499**	**6,159**	**5,631**	**5,193**	**5,036**	**4,757**	**4,688**	**4,966**	**6**	**6**
NSF	**2,102**	**1,847**	**1,690**	**1,670**	**1,533**	**1,471**	**1,353**	**1,346**	**14**	**9**
Agriculture	**1,256**	**1,219**	**1,108**	**1,038**	**1,017**	**948**	**929**	**943**	**3**	**6**
Agricultural Research Service	624	589	546	524	506	479	463	470	6	6
Cooperative State Research Service	373	377	324	307	298	271	269	284	–1	6
Forest Service	163	168	159	131	136	127	113	113	–3	8
EPA	**483**	**425**	**420**	**380**	**347**	**348**	**317**	**320**	**14**	**9**
Interior	**562**	**589**	**509**	**469**	**417**	**404**	**385**	**392**	**–5**	**7**
Geological Survey	339	354	308	280	236	227	219	215	–4	10
Commerce	**539**	**526**	**438**	**398**	**389**	**402**	**399**	**399**	**2**	**6**
National Oceanic & Atmospheric Administration	377	336	300	269	263	286	275	270	12	7
National Institute of Standards & Technology	186	176	122	116	108	99	101	101	6	13
Others	**1,892**	**1,806**	**1,664**	**1,384**	**1,293**	**1,298**	**1,325**	**1,424**	**5**	**7**
TOTAL	**$70,427**	**$63,218**	**$63,667**	**$61,406**	**$56,935**	**$55,253**	**$51,412**	**$48,360**	**11%**	**8%**
ANNUAL CHANGE	**11%**	**–1%**	**4%**	**8%**	**3%**	**7%**	**6%**	**14%**		

Note: Fiscal years. a Estimated. Source: National Science Foundation

PERFORMERS OF FEDERALLY FUNDED R&D: Industry's share is growing

Federal obligations, $ millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Industry	$34,307	$29,237	$31,616	$30,508	$28,630	$28,628	$25,898	$23,496	17%	6%
FFRDCs[b] administered by industry	2,377	2,267	2,238	1,960	1,911	1,860	1,697	1,791	5	4
Federal intramural programs	17,645	16,469	16,003	15,121	14,115	13,413	13,535	12,945	7	7
Universities and colleges	14,601	13,763	12,608	12,169	11,302	10,547	9,327	9,156	6	7
FFRDCs[b] administered by universities	4,126	3,695	3,466	3,497	3,474	3,210	2,768	2,816	12	6
Nonprofit institutions	3,333	3,226	2,882	2,521	2,188	2,222	2,228	2,388	3	5
FFRDCs[b] administered by nonprofit institutions	714	676	632	522	506	511	551	689	6	1
Foreign	292	282	345	919	392	295	296	245	4	3
State and local governments	250	241	214	167	142	148	128	129	4	10
TOTAL	$70,427	$63,218	$63,667	$61,406	$56,769	$55,253	$51,412	$48,359	11%	6%
ANNUAL CHANGE	11%	–1%	4%	8%	3%	7%	6%	15%		

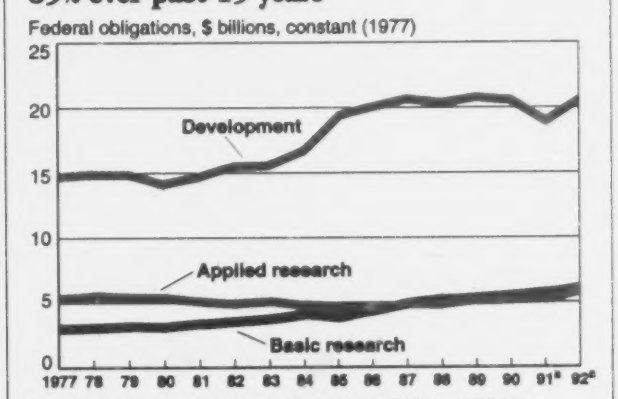
Note: Fiscal years **a** Estimated **b** Federally funded R&D centers **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: Physical sciences post 10% gain

$ Millions for research only	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Life sciences	$10,230	$ 9,670	$ 8,838	$ 8,495	$ 7,724	$ 7,341	$ 6,464	$ 6,363	6%	7%
Engineering	5,359	4,924	4,335	4,442	3,956	3,906	3,739	3,616	9	6
Metallurgy and materials	592	685	555	521	457	362	445	439	–14	4
Chemical	218	273	242	142	258	216	246	254	–20	–2
Physical sciences	4,523	4,123	3,809	3,705	3,317	3,253	3,069	3,046	10	6
Physics	2,610	2,423	2,255	2,191	1,975	1,854	1,806	1,816	8	5
Chemistry	872	834	762	783	703	680	662	650	5	4
Environmental sciences	2,627	2,450	2,174	1,773	1,607	1,512	1,482	1,404	7	9
Mathematical and computer sciences	1,007	946	841	735	643	641	615	575	6	8
Other sciences	1,937	1,958	1,742	1,615	1,402	1,287	1,133	1,129	–1	8
TOTAL	$25,683	$24,071	$21,739	$20,765	$18,649	$17,940	$16,502	$16,133	7%	7%
ANNUAL CHANGE	7%	11%	5%	11%	4%	9%	2%	8%		

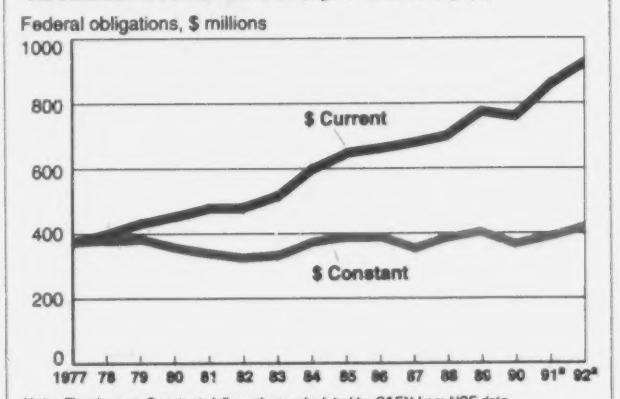
Note: Fiscal years **a** Estimated **Source:** National Science Foundation

Real support for basic research climbed 85% over past 15 years



Note: Fiscal years. Constant-dollar values calculated by C&EN from NSF data.
a Estimated. **Source:** National Science Foundation

In constant dollars, support for chemical research rose 9% since 1977



Note: Fiscal years. Constant-dollar values calculated by C&EN from NSF data.
a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: NIH provides almost 40% of the money

$ Millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Health & Human Services	**$ 5,419**	**$ 5,042**	**$ 4,649**	**$ 4,388**	**$4081**	**$3828**	**$3339**	**$3233**	**7%**	**8%**
National Institutes of Health	4,961	4,609	4,262	4,053	3795	3576	3119	3018	8	7
Alcohol, Drug Abuse & Mental Health Administration	456	431	386	308	266	232	203	197	6	13
NSF	**1,956**	**1,732**	**1,586**	**1,563**	**1433**	**1371**	**1275**	**1262**	**13**	**6**
NASA	**1,944**	**1,729**	**1,637**	**1,417**	**1113**	**1014**	**917**	**751**	**12**	**15**
Energy	**1,731**	**1,726**	**1,505**	**1,411**	**1185**	**1069**	**960**	**943**	**0**	**9**
Defense	**1,028**	**1,140**	**948**	**948**	**877**	**908**	**924**	**861**	**–10**	**3**
Navy	425	397	365	354	342	354	337	343	7	3
Air Force	212	185	197	203	196	222	217	198	15	1
Defense agencies	199	380	200	204	173	115	122	79	–48	14
Army	193	178	185	187	166	217	249	241	8	–3
Agriculture	**598**	**563**	**519**	**485**	**481**	**446**	**433**	**445**	**6**	**4**
Agricultural Research Service	336	318	294	283	271	253	248	250	6	4
Cooperative State Research Service	189	170	154	143	146	133	132	142	11	4
Forest Service	62	64	60	50	52	49	42	44	–3	5
Interior	**210**	**233**	**205**	**189**	**127**	**135**	**133**	**138**	**–10**	**6**
Geological Survey	168	182	159	140	90	85	83	81	–8	11
Bureau of Mines	34	44	41	44	32	46	45	50	–23	–6
EPA	**114**	**97**	**74**	**51**	**27**	**31**	**39**	**39**	**18**	**17**
Commerce	**34**	**32**	**31**	**29**	**31**	**26**	**27**	**23**	**6**	**6**
National Institute of Standards & Technology	33	30	29	28	26	25	26	22	10	6
Others	**174**	**152**	**132**	**121**	**120**	**114**	**106**	**124**	**14**	**4**
TOTAL	**$13,208**	**$12,446**	**$11,286**	**$10,602**	**$9475**	**$8942**	**$8153**	**$7819**	**6%**	**5%**
ANNUAL CHANGE	**6%**	**10%**	**6%**	**12%**	**6%**	**10%**	**4%**	**11%**		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

ENGINEERING RESEARCH: Funding for chemical engineering has yo-yoed since 1987, rising

Federal obligations, $ millions	1992[a] All engineering	1992[a] Chemical engineering	1992[a] Metallurgy & materials	1991[a] All engineering	1991[a] Chemical engineering	1991[a] Metallurgy & materials	1990 All engineering	1990 Chemical engineering	1990 Metallurgy & materials
Defense	**$1963.1**	**$31.2**	**$386.6**	**$1972.2**	**$ 32.4**	**$487.8**	**$1762.2**	**$ 37.4**	**$370.5**
Defense agencies	574.2	0.3	244.6	720.8	0	359.4	509.8	0	240.8
Air Force	494.7	3.7	45.7	419.0	3.3	38.6	466.7	1.8	42.6
Navy	478.4	11.2	68.3	443.8	10.3	62.5	408.8	11.5	59.7
Army	415.8	16.0	28.0	388.5	18.7	27.2	377.0	24.0	27.3
NASA	**1960.7**	**16.4**	**81.5**	**1519.2**	**13.4**	**68.4**	**1324.6**	**14.3**	**59.8**
Energy	**488.6**	**69.2**	**73.1**	**528.3**	**138.7**	**78.1**	**435.6**	**105.9**	**78.5**
NSF	**220.6**	**44.4**	**9.7**	**186.8**	**38.5**	**8.4**	**171.6**	**35.9**	**7.8**
Transportation	**108.3**	**6.2**	**1.0**	**117.6**	**6.8**	**0.9**	**91.9**	**7.0**	**0.2**
Interior	**83.7**	**9.7**	**25.8**	**100.8**	**6.9**	**27.6**	**88.4**	**5.8**	**25.1**
EPA	**72.6**	**28.4**	**0.6**	**64.9**	**25.0**	**0.5**	**61.5**	**24.5**	**0.7**
Commerce	**76.0**	**4.2**	**13.6**	**70.8**	**4.0**	**13.6**	**56.8**	**3.9**	**11.8**
Agriculture	**36.8**	**7.9**	**0**	**41.2**	**7.8**	**0**	**38.9**	**7.3**	**0**
TOTAL	**$5010.4**	**$217.6**	**$591.9**	**$4602.0**	**$273.5**	**$685.3**	**$4031.5**	**$242.0**	**$554.4**
ANNUAL CHANGE	**9%**	**–20%**	**–14%**	**14%**	**13%**	**24%**	**–5%**	**70%**	**6%**

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR CHEMICAL RESEARCH: **Growing by just 4% per year**

$ Millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Energy	**$182.3**	**$214.4**	**$189.2**	**$213.4**	**$162.9**	**$145.5**	**$145.9**	**$143.0**	**–15%**	**4%**
NSF	**156.0**	**140.9**	**133.2**	**127.4**	**120.6**	**115.3**	**112.6**	**115.6**	**11**	**4**
Defense	**132.3**	**118.4**	**121.0**	**133.5**	**125.0**	**144.9**	**163.4**	**156.4**	**12**	**–3**
Army	51.7	43.0	50.4	60.4	57.5	72.2	81.4	78.2	20	–5
Air Force	46.9	40.0	41.2	43.2	43.6	43.3	42.0	39.5	17	2
Navy	30.5	29.2	26.5	25.5	22.1	28.4	39.1	38.3	4	–4
Defense agencies	3.2	6.3	2.8	4.4	1.8	1.1	0.9	0.4	–49	35
Health & Human Services	**131.7**	**122.4**	**112.2**	**107.8**	**123.8**	**115.5**	**104.2**	**99.1**	**8**	**4**
National Institutes of Health	118.8	110.7	102.2	98.6	114.4	108.1	99.5	95.1	7	3
Alcohol, Drug Abuse & Mental Health Administration	12.9	11.7	9.9	9.2	9.4	7.4	4.7	4.0	10	18
Agriculture	**78.3**	**75.4**	**67.8**	**61.0**	**60.8**	**65.0**	**58.6**	**58.0**	**4**	**4**
Agricultural Research Service	50.7	47.9	43.1	41.3	40.9	46.4	40.0	36.1	6	5
Cooperative State Research Service	18.3	17.9	15.6	12.3	12.2	11.5	12.4	16.1	2	2
Forest Service	9.3	9.6	9.0	7.5	7.6	7.1	6.2	5.7	–3	2
EPA	**63.0**	**44.7**	**37.1**	**32.5**	**30.6**	**34.6**	**20.1**	**17.5**	**41**	**7**
NASA	**57.9**	**41.3**	**35.9**	**47.4**	**27.5**	**13.4**	**11.8**	**16.3**	**40**	**20**
Interior	**28.5**	**28.3**	**22.9**	**22.0**	**21.9**	**20.9**	**20.3**	**19.4**	**1**	**6**
Geological Survey	28.3	28.2	22.9	21.9	20.8	20.2	19.4	18.4	0	6
Commerce	**26.9**	**27.2**	**25.0**	**24.4**	**23.6**	**22.9**	**19.1**	**17.7**	**–1**	**8**
National Institute of Standards & Technology	20.9	19.5	18.4	17.7	16.9	16.5	16.4	15.4	7	4
National Oceanic & Atmospheric Administration	6.0	7.8	6.7	6.7	6.7	6.4	2.4	1.4	–23	23
Others	**15.5**	**20.8**	**17.5**	**13.3**	**6.4**	**2.4**	**6.3**	**1.5**	**–25**	**39**
TOTAL	**$872.4**	**$833.8**	**$761.8**	**$782.8**	**$703.1**	**$680.4**	**$662.3**	**$644.5**	**5%**	**4%**
ANNUAL CHANGE	**5%**	**9%**	**–3%**	**11%**	**3%**	**3%**	**3%**	**6%**		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

only 1%, whereas all engineering experienced a 35% increase

1989			1988			1987		
All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials
$1836.2	**$ 46.9**	**$343.4**	**$1636.1**	**$ 41.9**	**$294.4**	**$1629.7**	**$ 46.9**	**$203.6**
565.1	0.2	221.6	416.8	0.1	174.8	325.6	0	79.8
480.5	11.6	42.9	455.1	1.8	43.2	460.3	1.8	34.5
389.9	11.6	56.1	379.8	19.6	52.5	401.5	21.3	57.2
400.6	23.4	22.7	384.4	20.3	23.8	442.4	23.8	32.1
1446.4	**6.0**	**35.5**	**1138.2**	**2.0**	**18.8**	**1170.5**	**1.5**	**19.9**
406.1	**4.5**	**78.0**	**479.5**	**134.5**	**78.4**	**442.2**	**88.9**	**77.1**
232.0	**42.5**	**28.1**	**206.8**	**38.9**	**25.6**	**191.7**	**37.3**	**22.9**
87.6	**6.9**	**0.2**	**71.9**	**1.0**	**3.6**	**48.1**	**1.0**	**0.7**
92.8	**5.8**	**23.4**	**85.3**	**5.1**	**24.8**	**87.8**	**5.0**	**28.5**
52.7	**19.2**	**0.8**	**50.7**	**24.2**	**0.3**	**55.4**	**25.6**	**0.5**
52.7	**3.2**	**11.6**	**49.3**	**2.7**	**10.6**	**41.3**	**2.4**	**8.6**
34.5	**7.2**	**0**	**31.7**	**7.7**	**0**	**33.9**	**6.9**	**0**
$4241.0	**$142.2**	**$521.0**	**$3749.5**	**$258.0**	**$456.5**	**$3700.6**	**$215.5**	**$361.8**
13%	**–45%**	**14%**	**1%**	**20%**	**26%**	**5%**	**–12%**	**3%**

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: NASA's budget up 29% in 1992

$ Millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Health & Human Services	$ 3,252	$ 3,159	$ 2,818	$ 2,700	$2416	$2194	$1851	$1796	3%	9%
National Institutes of Health	2,385	2,248	2,074	2,008	1886	1740	1469	1410	6	8
Alcohol, Drug Abuse & Mental Health Administration	513	478	415	385	287	241	192	180	7	16
Defense	2,883	2,665	2,582	2,708	2362	2440	2303	2307	8	3
Defense agencies	1,060	1,049	965	1,038	792	751	735	738	1	5
Army	670	608	595	636	588	693	579	583	10	3
Air Force	639	527	579	605	577	563	542	538	21	3
Navy	515	482	443	429	406	433	447	448	7	2
NASA	2,232	1,734	1,424	1,461	1219	1256	1152	1033	29	12
Energy	1,212	1,237	1,066	1,021	1051	1029	1081	1198	–2	0
Agriculture	614	614	550	517	505	473	464	466	0	4
Agricultural Research Service	249	236	218	209	208	201	188	192	6	4
Cooperative State Research Service	185	206	171	165	153	138	137	143	–10	4
Forest Service	96	99	94	78	80	74	68	66	–3	6
Commerce	418	413	346	322	312	313	313	301	1	5
National Oceanic & Atmospheric Administration	291	292	252	235	225	234	238	224	0	4
National Institute of Standards & Technology	118	110	83	78	73	64	64	65	7	9
Interior	310	316	270	253	266	247	235	231	–2	4
Geological Survey	153	154	134	127	136	132	128	130	–1	2
EPA	281	246	242	223	241	246	179	176	14	7
NSF	136	115	103	108	100	99	78	84	18	7
Others	1,137	1,123	1,052	848	703	697	691	723	1	7
TOTAL	$12,475	$11,622	$10,453	$10,161	$9175	$8994	$8347	$8315	7%	6%
ANNUAL CHANGE	7%	11%	3%	11%	2%	8%	0%	5%		

Note: Fiscal years **a** Estimated **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR DEVELOPMENT: Biggest gains at Defense Department

$ Millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Defense	$34,858	$30,160	$33,739	$33,921	$32,010	$31,884	$29,711	$26,623	16%	5%
Air Force	14,265	11,188	14,055	14,430	14,094	14,563	12,835	12,524	28	2
Navy	7,488	7,971	8,779	8,883	8,766	8,721	8,866	8,336	–6	–2
Defense agencies	7,222	6,018	5,780	5,617	4,868	4,354	3,911	1,965	20	30
Army	5,595	4,771	4,904	4,836	4,052	4,110	3,982	3,747	17	6
NASA	4,367	3,971	3,473	2,515	1,999	1,518	1,351	1,544	10	16
Energy	3,556	3,196	3,060	2,761	2,801	2,659	2,648	2,825	11	3
Health & Human Services	1,109	1,046	939	814	661	584	468	423	6	15
National Institutes of Health	907	848	801	717	610	536	418	400	7	12
Transportation	299	269	247	182	213	256	317	358	11	–3
Commerce	87	81	61	47	47	64	60	75	7	2
National Oceanic & Atmospheric Administration	46	43	48	34	35	52	37	45	7	0
National Institute of Standards & Technology	36	35	11	10	9	9	12	14	3	15
EPA	87	83	104	107	80	71	100	106	5	–4
Agriculture	44	42	39	36	31	29	32	32	5	5
Agricultural Research Service	38	36	33	31	26	24	27	28	6	5
Interior	42	40	33	27	24	22	17	22	5	11
Geological Survey	18	18	15	13	11	10	7	4	0	24
Others	293	259	233	230	253	226	207	219	13	6
TOTAL	$44,742	$39,147	$41,928	$40,640	$38,119	$37,313	$34,911	$32,227	14%	7%
ANNUAL CHANGE	14%	–7%	3%	7%	2%	7%	8%	18%		

Note: Fiscal years **a** Estimated **Source:** National Science Foundation

UNIVERSITY RESEARCH: Physical sciences get 13% of federal funds

Federal obligations, $ millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
Life sciences	$5288	$4990	$4532	$4396	$4029	$3824	$3252	$3192	6%	8%
Physical sciences	1152	1103	1002	930	857	823	752	750	4	6
Physics	624	621	546	486	425	404	405	402	0	7
Chemistry	351	330	317	298	295	281	266	267	6	4
Engineering	853	867	713	749	673	600	609	507	–2	8
Metallurgy and materials	182	215	166	194	175	108	133	107	–15	8
Chemical	48	45	59	42	57	55	51	46	7	1
Environmental sciences	595	560	489	460	408	400	366	361	6	7
Mathematical and computer sciences	477	460	415	345	305	289	274	253	4	9
Other sciences	724	738	636	593	494	449	365	348	–2	11
TOTAL	$9089	$8718	$7787	$7473	$6766	$6385	$5618	$5411	4%	8%
ANNUAL CHANGE	4%	12%	4%	10%	6%	14%	4%	13%		

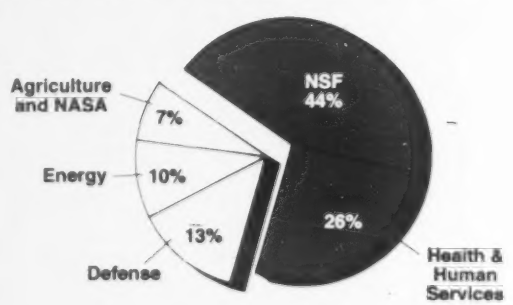
Note: Fiscal years. Includes funding only from six agencies that together represent about 96% of federal research support to universities. **a** Estimated. **Source:** National Science Foundation

UNIVERSITY RESEARCH IN CHEMISTRY: NSF and NASA grew strongly in 1992

Federal obligations, $ millions	1992[a]	1991[a]	1990	1989	1988	1987	1986	1985	% annual change 1991–92	% annual change 1985–92
NSF	$153.2	$138.3	$130.6	$118.5	$111.6	$107.1	$103.5	$108.1	11%	5%
Health & Human Services	91.5	85.1	79.9	76.5	91.4	85.0	75.0	75.2	8	4
National Institutes of Health	89.0	82.9	78.0	74.8	89.3	83.4	74.4	74.7	7	3
Alcohol, Drug Abuse & Mental Health Administration	2.5	2.2	1.9	1.6	2.1	1.6	0.6	0.6	14	33
Defense	46.9	47.0	41.9	42.0	41.3	45.0	43.2	40.4	0	2
Navy	19.1	17.7	16.2	14.3	13.6	17.2	13.9	15.5	8	3
Air Force	18.1	16.8	17.1	15.5	17.0	18.4	16.1	14.0	8	4
Army	6.5	6.2	5.8	7.7	8.8	[illegible]	12.4	10.9	5	–8
Defense agencies	3.2	6.3	2.8	4.4	1.8	1.1	0.9	0	–49	na
Energy	35.7	36.9	44.7	43.7	33.8	28.5	27.6	26.0	–3	5
Agriculture	16.3	16.4	14.4	11.8	11.8	11.2	12.2	15.5	–1	1
NASA	7.6	6.7	6.0	5.2	4.8	4.3	4.2	4.1	13	9
TOTAL	$351.2	$330.4	$317.5	$297.7	$294.7	$281.1	$265.7	$269.3	6%	4%
ANNUAL CHANGE	6%	4%	7%	1%	5%	6%	–1%	11%		

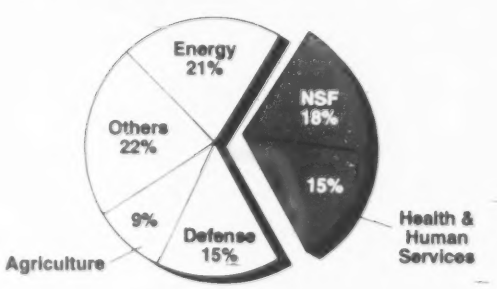
Note: Fiscal years. Data from these six agencies represent about 96% of federal obligations for fiscal 1992. **a** Estimated. **na** = not available. **Source:** National Science Foundation

Two agencies dominate federal funding for chemical research at universities . . .



Estimated fiscal 1992 federal obligations for university research in chemistry = $351 million[a]

. . . and provide just under a third of all chemical research funds

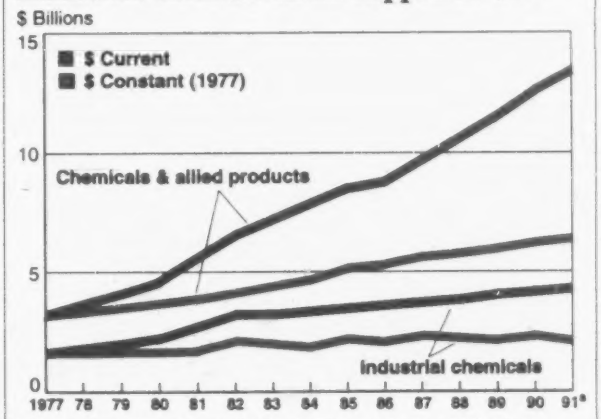


Estimated fiscal 1992 federal chemistry research obligations = $872 million

a Total is for these six agencies only. **Source:** National Science Foundation

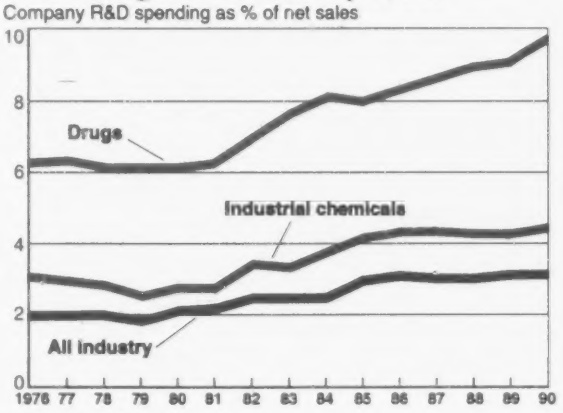
R&D Growth Eases Off in 1991

In constant dollars, R&D spending by industrial chemical firms slipped in '91



Note: Constant-dollar values calculated by C&EN from NSF data. a C&EN estimate.
Source: National Science Foundation

R&D's share of company revenue in all fields has grown since early 1980s



Source: National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Chemicals outpace other industries in 1991

$ Millions	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change 1990–91	% annual change 1981–91
Chemicals and allied products	$ 13,400[a]	$ 12,565	$ 11,466	$10,772	$ 9,878	$ 8,843	$ 8,540	$ 7,927	$ 7,185	$ 6,604	$ 5,625	7%	9%
Industrial chemicals	4,400[a]	4,344	4,039	3,959	3,901	3,552	3,498	3,240	3,214	3,206	2,802	1	5
Drugs	6,150[a]	5,654[a]	5,168[a]	4,746	4,158[a]	3,658	3,490[a]	3,316[a]	2,901[a]	2,481[a]	2,073[a]	9	12
Other chemicals	2,850[a]	2,567[a]	2,259[a]	2,067	1,819[a]	1,633	1,552[a]	1,371[a]	1,070[a]	917[a]	750[a]	11	14
Other Industries	93,350[a]	91,779	90,388	87,117	82,277	78,980	75,699	66,873	58,083	52,046	46,185	2	7
TOTAL	$106,750[b]	$104,344	$101,854	$97,889	$92,155	$87,823	$84,239	$74,800	$65,268	$58,650	$51,810	2%	8%

a C&EN estimates. b Preliminary. Source: National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: Outlays for chemical R&D grew 10% in 1990

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
Chemicals and allied products	$12,498	$11,383	$10,573	$ 9,445	$ 8,664	$ 8,310	$ 7,736	$ 6,792	$ 6,197	$ 5,205	$ 4,264	10%	11%
Industrial chemicals	4,280	3,960	3,763	3,531	3,374	3,281	3,057	2,828	2,810	2,393	1,856	8	9
Drugs	5,651	5,164	4,743	4,095	3,657	3,481	3,310	2,896	2,473	2,064	1,755[a]	9	12
Other chemicals	2,567	2,259	2,067	1,819	1,633	1,548	1,369	1,068	914	747	653	14	15
Other industries	48,768	47,796	44,626	42,513	51,268	48,733	43,668	37,796	33,908	30,223	26,212	2	6
TOTAL	$73,764	$70,562	$65,772	$61,403	$59,932	$57,043	$51,404	$44,588	$40,105	$35,428	$30,476	5%	9%

a C&EN estimates. Source: National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Chemical industry funds slashed in 1989 and 1990

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
Chemicals and allied products	$ 67	$ 83	$ 199	$ 192	$ 179	$ 230	$ 191[a]	$ 393	$ 407	$ 421	$ 372	–19%	–16%[a]
Industrial chemicals	64	79	196	187	178	217	183[a]	386	396	409	341	–19	–15[a]
Drugs and other chemicals	3	4	3	5	1	13	8	7	11	12	31	–25	–21
Other industries	30,446	31,126	31,719	31,119	27,712	26,966	23,205	20,287	18,138	15,961	13,657	–2	9
TOTAL	$30,580	$31,292	$32,117	$31,311	$27,891	$27,196	$23,396	$20,680	$18,545	$16,382	$14,029	–2%	8%

a The decline in 1984 from 1983 results from the administration of federally funded Oak Ridge National Laboratory being changed from a chemical company to a company in the aircraft and missile industry. **Source:** National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Funds spent by drug firms shot up 46% in 1990

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
Chemicals and allied products	$2005	$1504	$1501	$1243	$1071	$ 843	$ 786	$ 729	$ 682	$ 715	$ 603	33%	13%
Industrial and other chemicals	549	508	781	625	579	444	385	368	319	287	246	8	8
Drugs	1456	996	720	618	492	399	401	361	363	428	357	46	15
Other industries	3800	5232	4794	3983	3553	2807	2847	2540	2412	2678	2562	–27	4
TOTAL	$7810	$6814	$6295	$5226	$4624	$3650	$3633	$3269	$3094	$3393	$3165	15%	10%

Source: National Science Foundation

R&D SPENDING: Chemical firms curbed spending in 1991, drug firms held strong

$ Millions	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1991 R&D spending as % of sales
CHEMICAL COMPANIES												
Du Pont	$1298	$1428	$1387	$1319	$1223	$1156	$1144	$1097	$ 966	$ 879	$ 718	3.4%
Dow Chemical	1159	1136	873	772	670	605	547	507	492	460	404	6.2
Monsanto	627	612	598	648	615	596	470	370	290	264	233	8.0
American Cyanamid	492	460	406	365	314	278	251	232	208	185	166	9.9
Union Carbide	190	191	181	159	159	148	275	265	245	240	207	3.2
Rohm & Haas	183	178	175	156	142	133	124	109	100	92	77	6.6
W. R. Grace	150	148	125	119	107	94	92	81	73	64	57	2.5
Hercules	86	92	79	74	74	71	76	72	74	74	65	2.9
Air Products[a]	80	72	71	72	57	61	51	44	40	37	32	2.7
Lubrizol	80	74	70	65	62	51	44	33	37	36	33	5.4
Ethyl	69[b]	65[b]	61[b]	59[b]	50	47	47	40	39	39	37	2.7
International Flavors	62	57	52	50	45	39	34	32	32	31	30	6.1
Morton International[c]	59	48	38	35	31	29	25	30	23	7	6	3.1
Nalco	47	45	41	37	35	33	32	32	30	33	30	3.8
Olin	41	66	66	58	62	56	53	52	49	45	38	1.8
Petrolite[d]	11	12	12	12	12	12	12	12	13	10	8	3.5
TOTAL	$4634	$4684	$4235	$4000	$3658	$3409	$3277	$3008	$2711	$2496	$2141	4.3%
ANNUAL CHANGE	1%	11%	6%	9%	7%	4%	9%	11%	9%	17%	18%	
PHARMACEUTICAL COMPANIES												
Merck & Co.	$ 998	$ 854	$ 751	$ 669	$ 566	$ 480	$ 426	$ 393	$ 356	$ 320	$ 274	11.6%
Bristol-Myers Squibb	993	881	789	688	563	474	412	344	301	260	226	8.9
Eli Lilly	767	703	605	512	466	427	370	341	294	267	235	13.4
Pfizer	757	640	531	473	401	336	287	255	230	199	179	10.9
Upjohn	491	427	407	380	356	314	284	247	218	185	162	14.4
Schering-Plough	426	380	327	298	251	212	175	164	145	127	109	11.8
TOTAL	$4432	$3885	$3410	$3020	$2603	$2243	$1954	$1744	$1544	$1358	$1185	11.2%
ANNUAL CHANGE	14%	14%	13%	16%	16%	15%	12%	13%	14%	15%	15%	

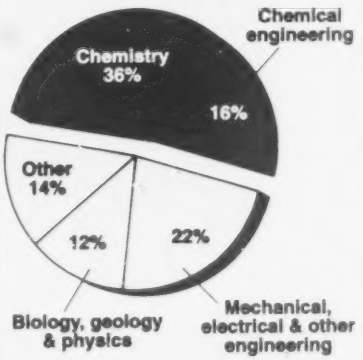
Note: Prior years are not restated to reflect company revisions. **a** For fiscal year ending Sept. 30. **b** Adjusted to reflect spin-off of Tredegar Industries. **c** For fiscal year ending June 30, includes all company-financed R&D but excludes contract R&D; data for Morton Thiokol prior to 1985. **d** For fiscal year ending Oct. 31. **Source:** Company data

CHEMISTS IN INDUSTRY: One fifth work in drug firms

Industry	% of industrial chemists: All chemists	B.S.	M.S.	Ph.D.	Mean salary ($ thousands)[a]: B.S.	M.S.	Ph.D.
MANUFACTURING							
Pharmaceuticals[b]	20%	16%	23%	22%	$45.0	$54.0	$74.8
Specialty chemicals	13	12	12	14	46.7	53.2	66.6
Basic chemicals	6	4	3	8	42.9	56.3	69.5
Plastics	5	4	4	6	47.5	57.4	70.8
Coatings	4	5	5	4	44.6	48.1	60.6
Petroleum and natural gas	4	4	3	5	47.7	57.8	75.6
Medical devices	3	2	3	4	40.0	56.4	66.6
Agricultural chemicals	3	3	3	4	39.9	50.4	67.9
Electronics	3	2	3	3	44.5	53.5	68.7
Food	3	4	4	2	41.6	55.1	68.2
Instruments	3	2	4	3	47.2	55.1	68.4
Aerospace	2	2	2	2	45.5	49.3	62.9
Rubber	2	3	2	1	46.6	45.7	62.1
Metals and minerals	2	2	2	1	41.8	48.6	62.8
Biochemical products	1	1	1	2	39.6	52.5	64.4
Soaps and detergents	1	2	1	1	39.9	55.6	69.8
Paper	1	1	1	2	42.6	52.4	63.1
Other	10	12	9	9	43.3	51.8	68.3
NONMANUFACTURING							
Analytical service labs	6	11	7	2	41.2	47.0	58.6
Contract research firms	3	2	2	4	43.0	52.0	59.8
Utilities	1	2	2	—	45.4	47.7	62.6
Other	4	6	5	3	46.2	54.9	62.6

a As of March 1, 1992, to facilitate comparison, mean salaries are adjusted for differences in average length of experience.
b Includes personal care products. **Source:** ACS survey

Chemical fields draw 52% of industrial R&D professionals



Total R&D scientists and engineers in industry in 1991 = 709,700

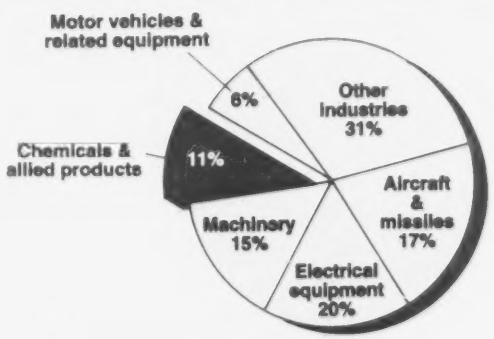
Note: Percentages represent distribution of scientists and engineers by area of work.
Source: Industrial Research Institute

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Chemical firms up but total drops 3%

Thousands	1991	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	% annual change: 1990–91	1981–91
Chemicals and allied products	**79.9**	**78.9**	**77.6**	**75.8**	**75.2**	**75.8**	**71.1**	**69.8**	**67.3**	**61.6**	**54.7**	**1%**	**4%**
Industrial chemicals	23.3[a]	23.0[a]	23.1[a]	22.5[a]	22.4[a]	24.9	23.5	25.6	26.6	25.9	21.6	1	1
Drugs	34.5	33.5	34.0	33.0	32.6	31.8	30.8	30.8[a]	28.2	25.6	23.3	3	4
Other chemicals	22.1	22.4	20.5	20.3	20.2	19.1	16.7	13.4	12.1	10.1	9.8	–1	9
Other industries	**629.8**	**652.0**	**642.6**	**632.8**	**620.6**	**595.2**	**551.4**	**514.3**	**473.6**	**448.2**	**433.1**	**–3**	**4**
TOTAL	**709.7**	**730.9**	**720.2**	**708.6**	**695.8**	**671.0**	**622.5**	**584.1**	**540.9**	**509.8**	**487.8**	**–3%**	**4%**

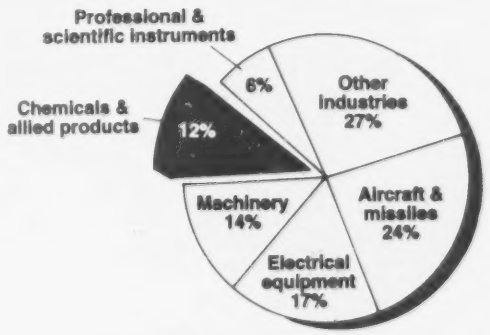
Note: Data as of January of each year for full-time equivalent personnel. a C&EN estimates. **Source:** National Science Foundation

Chemical producers employ 11% of industrial scientists and engineers . . .



1991 total industrial R&D scientists and engineers[a] = 709,700

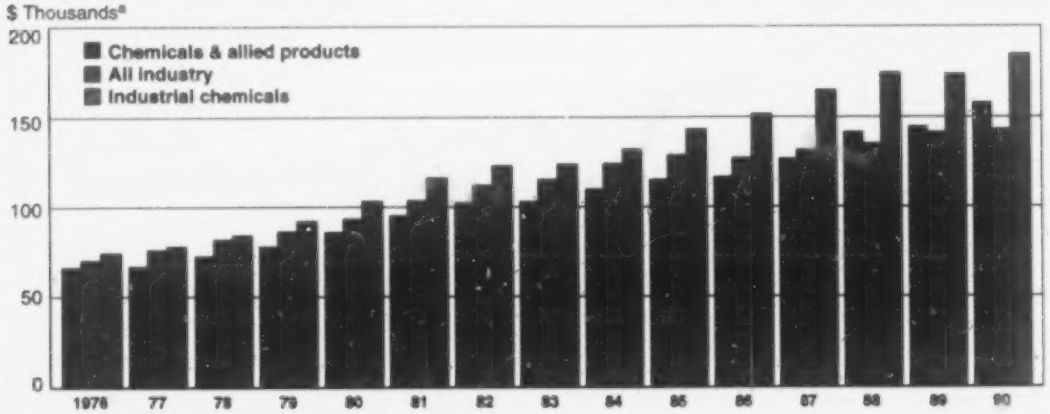
. . . and account for 12% of total industrial R&D spending in the U.S.



1990[b] total industrial R&D expenditures = $104 billion

a Data as of January 1991 for full-time equivalent personnel. b Latest year for which data are available. **Source:** National Science Foundation

Cost per R&D scientist is growing fastest in industrial chemical firms



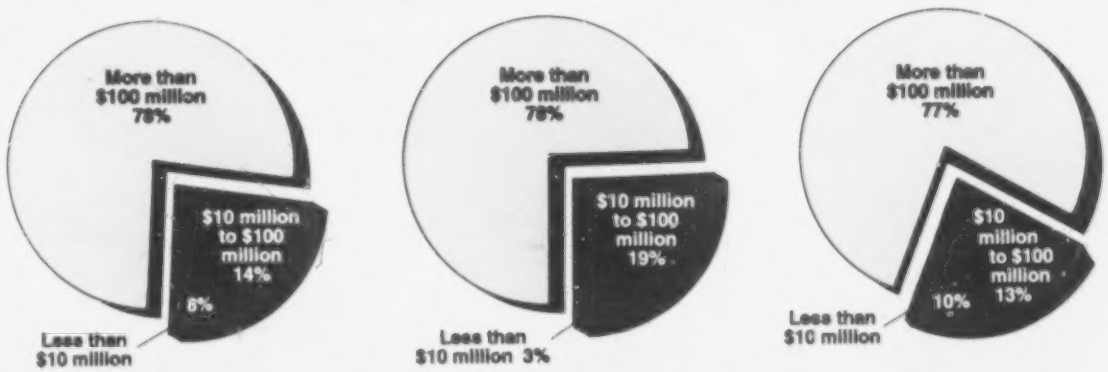
a Cost per industrial R&D scientist or engineer. Source: National Science Foundation

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: Chemical firms up 76% since '80

Thousands	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980
Chemicals and allied products	74	72	70	68	70	57	57	54	51	44	42
Industrial chemicals	57	56	55	52	56	39	41	45	44	37	36
Drugs	104	98	99	98	98	81	89	82	74	66	60
Other chemicals	64	63	61	61	63	62	51	39	37	33	30
All industry	49	49	47	45	45	43	40	34	33	29	27

Source: National Science Foundation

Chemical firms with research budgets under $100 million do more than a fifth of all R&D


More than $100 million 78%
$10 million to $100 million 14%
6%
Less than $10 million
More than $100 million 78%
$10 million to $100 million 19%
Less than $10 million 3%
More than $100 million 77%
$10 million to $100 million 13%
10%
Less than $10 million

1990 chemicals and allied products R&D funds = $12.6 billion

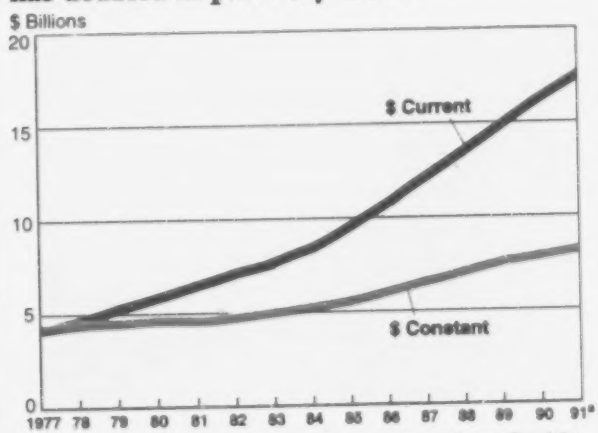
1990 industrial chemicals R&D funds = $4.3 billion

1990 industry R&D funds = $104 billion

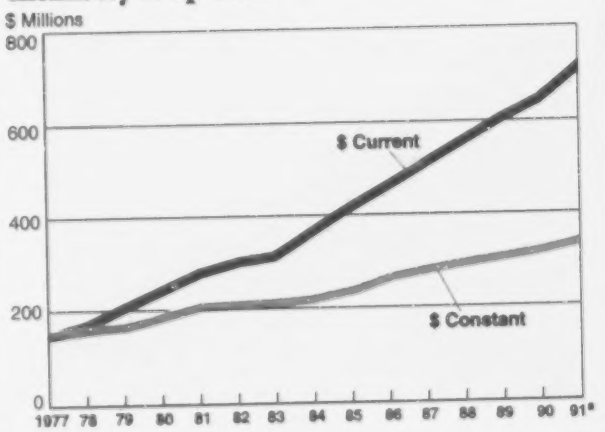
Note: Ranges indicate size of companies' 1990 R&D programs. Source: National Science Foundation

Academic R&D Outlays Top $16 Billion

In real terms, academic R&D spending has doubled in past 15 years . . .



. . . and spending for work in chemistry is up 116%



Note: Data for academic years. a C&EN estimates. Source: National Science Foundation

CHARACTER OF ACADEMIC R&D SPENDING: Basic research took 64% in 1990

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
Basic research	$10,431	$ 9,710	$ 8,827	$ 8,398	$ 7,495	$6559	$5735	$5304	$4882	$4596	$4041	7%	10%
Applied research and development	5,894	5,299	4,637	3,756	3,431	3128	2882	2573	2441	2250	2035	11	11
TOTAL	**$16,325**	**$15,009**	**$13,464**	**$12,154**	**$10,926**	**$9687**	**$8617**	**$7877**	**$7323**	**$6846**	**$6077**	**9%**	**10%**
ANNUAL CHANGE	**9%**	**11%**	**11%**	**11%**	**13%**	**12%**	**9%**	**8%**	**7%**	**13%**	**13%**		

Note: Data for academic years. Source: National Science Foundation

SOURCE OF ACADEMIC R&D FUNDS: Industry's share has almost doubled in 10 years

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
Federal government	$ 9,611	$ 8,984	$ 8,181	$ 7,333	$ 6,703	$6057	$5424	$4983	$4763	$4565	$4104	7%	9%
Institutional funds	3,017	2,712	2,364	2,176	1,873	1622	1414	1303	1115	1008	837	11	14
State and local governments	1,338	1,234	1,107	1,024	916	754	690	626	616	546	496	8	10
Industry	1,135	998	871	789	699	559	475	388	337	291	236	15	17
Other sources	1,223	1,081	941	831	735	695	615	577	492	436	403	13	12
TOTAL	**$16,324**	**$15,009**	**$13,464**	**$12,153**	**$10,926**	**$9687**	**$8618**	**$7877**	**$7323**	**$6846**	**$6077**	**9%**	**10%**

Note: Data for academic years. Source: National Science Foundation

FIELDS OF ACADEMIC R&D SPENDING: Chemical research accounts for 4%

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
All sciences	$13,642	$12,606	$11,367	$10,262	$ 9,287	$8271	$7388	$6759	$6281	$5861	$5196	8%	10%
Life	8,763	8,088	7,256	6,533	5,893	5282	4713	4304	4016	3689	3218	8	11
Physical	1,781	1,641	1,545	1,389	1,286	1148	1000	900	823	765	678	9	10
Physics	834	774	730	665	630	551	474	417	367	357	322	8	10
Chemistry	649	608	565	513	469	421	371	335	308	285	245	7	10
Environmental	1,047	989	885	831	773	703	644	616	557	550	509	6	7
Psychology and social	962	875	767	690	633	541	504	481	484	494	453	10	8
Computer	503	468	410	373	323	283	225	187	149	132	114	7	16
Mathematical	221	215	199	177	152	128	123	106	96	87	79	3	11
Others	365	330	305	269	228	186	179	165	156	145	146	11	10
Engineering	2,682	2,404	2,097	1,892	1,638	1415	1229	1120	1041	968	866	12	12
Chemical	206	185	154	141	126	110	96	91	84	76	68	11	12
TOTAL	$16,342	$15,010	$13,464	$12,154	$10,925	$9686	$8617	$7879	$7322	$6829	$6062	9%	10%
ANNUAL CHANGE	9%	11%	11%	11%	13%	12%	9%	8%	7%	13%	13%		

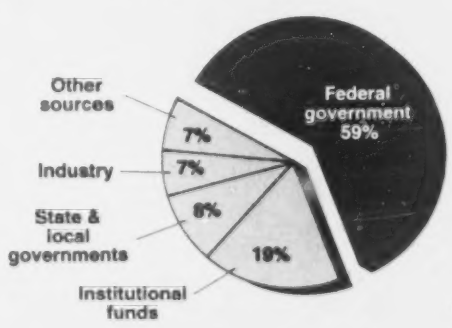
Note: Data for academic years. Data since 1981 were revised in 1989. **Source:** National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: Growth slows for chemistry

$ Millions	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
All sciences	$8076	$7601	$6951	$6220	$5727	$5192	$4637	$4249	$4059	$3898	$3500	6%	8%
Life	5068	4780	4318	3830	3489	3184	2827	2586	2502	2365	2094	6	9
Physical	1290	1193	1152	1046	982	890	782	699	650	619	555	8	8
Physics	647	598	574	530	510	453	390	343	307	309	280	8	9
Chemistry	443	422	403	368	338	313	279	247	230	217	190	4	9
Environmental	674	649	583	541	515	473	445	426	391	391	372	4	6
Psychology and social	394	368	329	292	287	260	241	236	250	280	263	7	4
Computer	334	318	289	257	233	196	163	139	107	93	77	5	16
Mathematical	159	156	149	131	114	97	92	76	72	68	61	2	10
Others	157	137	131	123	107	92	87	87	88	82	78	15	8
Engineering	1535	1385	1230	1112	976	865	787	733	703	662	596	11	10
Chemical	100	93	78	70	68	59	55	53	50	48	46	8	8
TOTAL	$9611	$8986	$8181	$7332	$6703	$5057	$5424	$4982	$4763	$4561	$4096	7%	9%
ANNUAL CHANGE	7%	10%	12%	9%	11%	12%	9%	5%	4%	11%	14%		

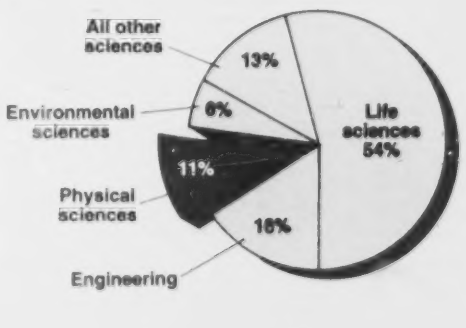
Note: Data for academic years. Data since 1981 were revised in 1989. **Source:** National Science Foundation

Federal government's share of all academic R&D slips below 60%



1990 academic R&D expenditures = $16.3 billion

Physical sciences claim about a tenth of academic R&D funds



1990 academic R&D expenditures = $16.3 billion

Source: National Science Foundation

TOP 10 UNIVERSITIES IN R&D SPENDING: Spending in life sciences dominates

Rank 1990	Rank 1989	$ Millions, 1990	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math & computer sciences	Other sciences	Total
1	1	Johns Hopkins U	$ 93.4	$ 5.4	$ 204.8	$ 41.4	$ 208.6	$ 97.0	$ 23.9	$ 669.1
2	2	Massachusetts Institute of Technology	98.1	17.1	127.0	12.4	37.7	14.7	22.0	311.9
3	6	U of Michigan	15.3	3.7	53.9	17.2	162.4	10.1	51.7	310.6
4	5	U of Wisconsin, Madison	29.5	8.9	39.8	22.0	178.3	7.9	32.4	309.9
5	4	Stanford U[b]	53.8	10.8	83.7	5.6	138.5	16.6	7.3	305.5
6	3	Cornell U	44.9	10.0	39.7	6.2	166.6	27.1	15.6	300.1
7	6	U of Minnesota	16.6	6.7	27.9	8.8	204.6	16.4	17.6	291.9
8	8	Texas A&M U	17.5	8.0	62.8	64.0	106.9	5.5	16.1	272.8
9	11	Pennsylvania State U	16.6	9.1	118.1	14.1	83.7	3.6	20.8	256.9
10	9	U of California, Los Angeles	23.1	11.2	24.2	12.2	157.6	7.4	22.2	246.7
		TOTAL, FIRST 10 INSTITUTIONS	$ 408.8	$ 90.9	$ 781.9	$ 204.0	$1444.9	$206.3	$ 229.6	$ 3,275.5
		TOTAL, ALL INSTITUTIONS	$1781.1	$649.4	$2681.8	$1047.3	$8763.5	$723.9	$1327.1	$16,324.7

Note: Data for academic years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1990 data with that reported in earlier years may be inappropriate in some areas. **a.** Included in physical sciences. **b.** Imputed.
Source: National Science Foundation

TOP 10 UNIVERSITY R&D CENTERS: Physical sciences get almost 40% of federal support

$ Millions, 1990	Physical sciences	Engineering	Math & computer sciences	Environmental sciences	Life sciences	Psychology & social sciences	Other sciences	Total
1 Jet Propulsion Lab	$ 76.1	$ 401.1	$499.3	$ 89.3	$ 0	$ 0	$ 0	$1065.8
2 Lawrence Livermore National Lab	315.5	487.5	152.7	33.3	30.9	0	0	1019.9
3 Los Alamos National Lab	443.1	316.4	91.8	6.4	33.0	29.0	6.4	926.1
4 Lincoln Lab	79.9	295.4	43.4	0	0	0.4	0	419.1
5 Argonne National Lab	90.1	163.1	5.0	75.5	13.9	0	0	347.6
6 Brookhaven National Lab	193.7	38.8	0.6	8.7	21.3	0.5	0.2	263.8
7 Lawrence Berkeley Lab	139.5	1.1	1.9	11.0	36.4	0	6.1	196.0
8 Fermi National Accelerator Lab	184.6	0	0	0	0	0	0	184.6
9 Stanford Linear Accelerator Center	115.2	0	0	0	0	0	0	115.2
10 Plasma Physics Lab	95.3	0	0	0	0	0	0	95.3
Eight others	90.7	4.6	26.7	67.8	6.8	0.2	0	196.8
TOTAL, TOP 18 FEDERALLY FUNDED R&D CENTERS	$1823.7	$1708.0	$821.4	$292.0	$142.3	$29.7	$12.7	$4830.2

Note: Data for university-administered, federally funded R&D centers. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1990 data with those reported in earlier years may be inappropriate in some areas.
Source: National Science Foundation

UNIVERSITY SPENDING FOR RESEARCH EQUIPMENT: Government provides 60% of the funds

	1990		1989		1983		% annual change 1989–90		% annual change 1983–90	
$ Millions	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds
All sciences	$ 794.1	$470.2	$789.0	$474.7	$374.4	$228.7	1%	1%	8%	7%
Life sciences	430.3	224.9	440.0	237.6	211.3	115.0	–2	–5	7	7
Physical sciences	187.7	140.6	179.7	132.4	81.0	63.6	4	6	8	8
Physics	89.6	73.1	82.0	64.5	36.7	30.6	9	13	9	9
Chemistry	72.7	51.2	75.4	52.6	32.6	23.2	–4	–3	8	8
Environmental sciences	69.9	46.2	65.4	43.9	31.1	19.2	7	5	8	9
Mathematical and computer sciences	54.8	35.0	52.5	35.9	24.6	17.0	4	–3	8	7
Other sciences	51.4	23.5	51.4	24.9	26.4	13.9	0	–6	7	5
Engineering	219.5	124.9	205.2	117.4	79.9	51.9	7	6	11	8
Chemical	17.2	7.8	18.6	9.4	6.0	3.5	–8	–17	11	8
TOTAL	$1013.6	$595.1	$994.2	$592.1	$454.3	$280.6	2%	0%	8%	8%

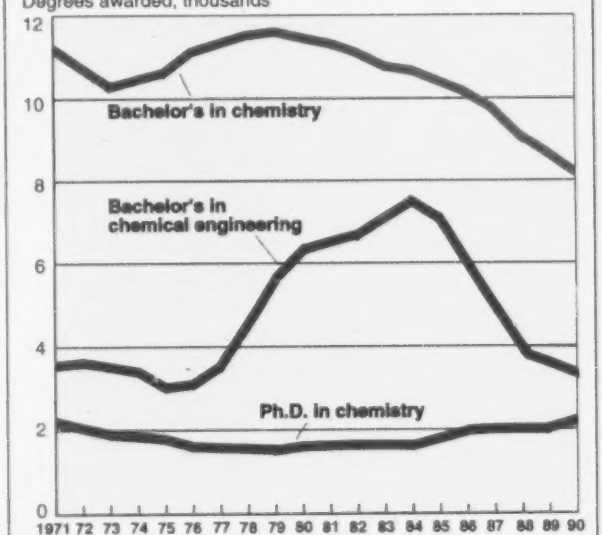
Note: Data for academic years. **Source:** National Science Foundation

CHEMICAL DEGREES: Only Ph.D. chemists posted gains in 1990

Academic year	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1971	11,183	2284	2160	3615	1100	406
1972	10,721	2259	1971	3663	1154	394
1973	10,226	2230	1882	3636	1051	397
1974	10,525	2138	1828	3454	1045	400
1975	10,649	2006	1824	3142	990	346
1976	11,107	1796	1623	3203	1031	308
1977	11,322	1775	1571	3581	1086	291
1978	11,474	1892	1525	4615	1237	259
1979	11,643	1765	1518	5655	1149	304
1980	11,446	1733	1551	6383	1271	284
1981	11,347	1654	1622	6527	1267	300
1982	11,062	1751	1722	6740	1285	311
1983	10,746	1604	1746	7145	1304	319
1984	10,704	1667	1744	7475	1514	330
1985	10,482	1719	1789	7146	1544	418
1986	10,116	1754	1908	5877	1361	446
1987	9,661	1738	1976	4983	1184	497
1988	9,052	1708	1995	3917	1088	579
1989	8,654	1785	2034	3684	1097	599
1990	8,126	1696	2183	3450	1030	564

Source: National Center for Education Statistics

Bachelor's degrees continue to decline



Note: Academic years. **Source:** National Center for Education Statistics

POSTDOCTORAL APPOINTEES: Chemistry, biochemistry account for 29% of all in sciences

	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
All sciences	20,444	19,321	18,182	17,469	16,591	15,628	15,017	14,598	13,694	13,742	13,035	6%	5%
Biological sciences	12,498	11,723	10,885	10,515	9,816	9,226	8,758	8,404	7,756	7,707	7,106	7	6
Biochemistry	2,319	2,244	2,090	2,121	1,989	1,866	1,789	1,750	1,684	1,724	1,599	3	4
Physical sciences	5,545	5,355	5,187	4,953	4,843	4,517	4,386	4,444	4,281	4,462	4,264	4	3
Chemistry	3,610	3,462	3,429	3,246	3,151	2,995	2,906	2,973	2,805	2,870	2,710	4	3
Physics	1,721	1,678	1,578	1,548	1,527	1,342	1,320	1,350	1,326	1,445	1,398	3	2
Psychology and social sciences	967	916	818	839	852	853	761	788	803	803	913	6	1
Earth, atmospheric, and ocean sciences	611	459	499	420	417	375	488	415	335	339	308	33	7
Agricultural sciences	499	477	422	414	388	357	358	295	279	284	239	5	8
Mathematical and computer sciences	324	301	271	329	275	300	266	252	240	147	205	8	5
Engineering	1,953	1,914	1,684	1,442	1,398	1,347	1,194	1,101	978	1,040	978	2	7
Chemical	551	466	423	310	295	273	245	198	174	171	183	18	12
Metallurgical and materials	368	323	325	282	249	245	168	204	166	193	172	14	8
TOTAL	22,397	21,145	19,866	18,911	17,989	16,975	16,211	15,699	14,672	14,782	14,013	6%	5%
ANNUAL CHANGE	6%	6%	5%	5%	6%	5%	3%	7%	–1%	5%	–		

Source: National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL R&D: Top 10 account for almost 20% of total

Rank 1990	Rank 1989		1990 Total spending ($ thousands)	1990 % federal funds	1989	1988	1987	1986	1985	% annual change 1989–90	% annual change 1985–90
					($ thousands)						
1	1	**Massachusetts Inst. of Technology**	$ 17,109	88%	$ 15,031	$ 13,287	$ 11,471	$ 13,593	$ 13,221	14%	5%
2	2	**U of California, Berkeley**	13,804	88	12,663	14,285	12,490	9,114	10,804	9	5
3	4	**U of Texas, Austin**	13,259	51	11,484	10,943	11,420	8,531	7,908[a]	15	11
4	3	**Harvard U**	13,114	90	11,856	9,886	8,895	7,202	6,557	11	15
5	7	**U of California, Los Angeles**	11,217	91	9,855	9,519	10,099	7,954	7,243	14	9
6	9	**U of Maryland, College Park**	10,977	43	9,732	8,545	9,258	7,904	7,289	13	9
7	6	**Stanford U**	10,752[b]	87	10,098	10,547	8,916	8,340	8,354	7	5
8	11	**California Inst. of Technology**	10,667	81	9,235	9,931	10,870	9,176	7,605	6	7
9	5	**Cornell U**	10,042	72	10,217	10,472	8,397	7,376[a]	7,962[a]	−2	5
10	10	**U of Chicago**	9,331	91	9,333	8,046	7,514	7,553	6,921	0	6
		Total, first 10 institutions	$120,272	79%	$109,504	$105,461	$ 99,330	$ 86,743	$ 83,864	10%	8%
11	22	**Rockefeller U**	9,248	47	7,471	6,975	6,823	7,335	11,826	24	9
12	73	**U of Massachusetts**	9,245	59	2,988	5,280	7,589	6,967	6,420	209	8
13	12	**U of Illinois, Urbana**	9,243	71	9,208	8,647	9,035	8,604	7,079	0	5
14	15	**Pennsylvania State U**	9,148	30	8,616	7,739	6,072	6,438	6,509	6	7
15	13	**Princeton U**	9,099	68	8,873	8,087	6,477	5,702	3,963	2	18
16	16	**U of Wisconsin, Madison**	8,937	61	8,326	7,282	6,984	7,892	7,350	7	4
17	14	**Purdue U**	8,672	79	8,769	8,615	7,092	6,315[a]	6,018	−1	8
18	17	**Case Western Reserve U**	8,252[a]	51	8,233	7,996	7,164	2,922	2,802	0	24
19	27	**U of California, San Diego**	8,120	91	6,487	6,780	5,179	6,535	4,642	25	12
20	20	**U of Pennsylvania**	8,077	91	7,760	7,292	6,741	6,064	5,025	4	10
		Total, first 20 institutions	$208,313	75%	$186,235	$180,154	$168,486	$151,526	$138,498	12%	9%
21	8	**Texas A&M U**	8,046	46	9,808	8,785	7,462	7,230[a]	6,768[a]	−18	
22	36	**Arizona State U**	7,967	46	5,260	4,306	3,586	4,124	2,703	51	24
23	19	**Rutgers U**	7,812	84	7,905	5,926	3,913	3,507	2,368	−1	5
24	18	**Indiana U**	7,344	83	7,927	7,991	6,181	6,110	5,820	−7	7
25	21	**Northwestern U**	7,219	76	7,661	6,644	6,095	4,826	5,062	−6	8
26	33	**U of Oregon**	6,760	77	5,501	5,650	4,462	5,087	4,640	23	10
27	29	**U of Minnesota**	6,663	88	5,863	5,232	5,426	5,110	4,167	14	10
28	46	**U of Rochester**	6,537	92	4,762	4,437	3,545	3,584	3,196	37	15
29	25	**U of Notre Dame**	6,348	89	6,660	7,004	5,550	5,402	5,549	−5	3
30	39	**Virginia Polytechnic Inst. & State U**	6,321	40	5,155	4,735	4,190	3,786	4,840	23	5
		Total, first 30 institutions	$279,330	73%	$252,737	$240,764	$218,896	$200,292	$183,611	11%	9%
31	24	**Ohio State U**	6,225	66	6,771	7,568	5,755	6,546	5,422	−8	3
32	37	**U of Washington**	6,057	68	5,192	4,338	3,655	2,971	2,964	17	15
33	26	**U of Colorado**	6,041	86	6,587	5,637	5,118	6,535	4,642	−8	5
34	28	**Yale U**	6,037	87	5,915	6,869[a]	5,538	5,110	4,167	2	8
35	23	**Columbia U, main division**	5,858	96	4,721[a]	4,605	6,715	5,555	5,138	24	5
36	30	**U of Pittsburgh**	5,832	81	5,736	5,598	5,105	4,974	4,580	2	5
37	53	**U of Southern California**	5,667	96	4,374	3,832	3,311	3,164	2,463	30	18
38	32	**Wayne State U**	5,455	33	5,557	4,582	3,278	3,405	2,903	−2	13
39	44	**U of Kansas**	5,450	38	4,952	3,845	2,803	1,808	1,875[b]	10	24
40	40	**Johns Hopkins U**	5,435	92	5,152	5,211	5,593	5,506	4,650[a]	5	3
		Total, first 40 institutions	$337,387	73%	$307,694	$292,849	$265,767	$245,866	$222,467	10%	9%
41	42	**U of Florida**	5,396	54	5,061	5,030	5,690	4,750	4,380	7	4
42	34	**Florida State U**	5,345	25	5,382	4,308	3,841	4,047	3,276	−1	10
43	38	**U of North Carolina, Chapel Hill**	5,310	87	5,171	4,476	3,471	3,352	3,386	3	9
44	41	**U of Virginia**	5,281	76	5,096	4,153	4,169	3,436	3,046	4	12
45	35	**Georgia Inst. of Technology**	5,215	56	5,380	5,989	4,889	5,260	3,684	−3	7
46	31	**U of Utah**	5,089	74	5,653	4,600	4,846	5,354	4,840	−10	1
47	51	**U of Arizona**	5,034	64	4,532	3,934	3,441	3,016	2,217	11	18
48	47	**State U of New York, Stony Brook**	4,897	78	4,754	5,010	3,669	3,333	3,481	3	7
49	60	**U of California, Irvine**	4,835	92	3,910	4,534	3,541	3,486	5,877	24	−4
50	50	**State U of New York, Buffalo**	4,770	62	4,644	3,903	3,370	2,837	2,768	3	11
		Total, first 50 institutions	$388,559	73%	$357,277	$338,786	$306,694	$284,737	$259,422	9%	8%
		NATIONAL TOTAL	$649,432	68%	$608,029	$565,293	$513,116	$469,275	$421,506	7%	9%

Note: Data for academic fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1990 data with those reported in earlier years may be inappropriate in some areas. Data for 1986 and later were revised in 1989. **a** Estimate. **b** Imputed. **Source:** National Science Foundation

SCHOOLS WITH MOST FEDERAL SUPPORT FOR CHEMICAL R&D: **Top 10 receive 22%**

Rank 1990	Rank 1989		1990	1989	1988	1987	1986	1985	% annual change 1989–90	% annual change 1985–90
			($ thousands)							
1	1	**Massachusetts Inst. of Technology**	$ 15,129	$ 13,333	$ 11,987	$ 10,656	$ 12,909	$ 12,424	13%	4%
2	2	**U of California, Berkeley**	12,219	11,450	12,998	11,160	8,258	9,892	7	4
3	3	**Harvard U**	11,855	10,594	9,272	8,309	6,748	6,557	12	13
4	4	**U of California, Los Angeles**	10,216	9,024	8,885	9,414	7,516	6,389	13	10
5	5	**Stanford U**	9,355[a]	8,878	9,423	7,918	7,524	7,097	5	6
6	7	**California Inst. of Technology**	8,629	7,459	8,769	9,922	7,612	7,001	16	4
7	6	**U of Chicago**	8,524	8,621	7,235	6,499	6,799[a]	6,265[a]	–1	6
8	18	**U of California, San Diego**	7,422	5,757	6,161	4,599	5,918	4,053	29	13
9	10	**U of Pennsylvania**	7,330	7,046	6,337	5,653	5,232	4,938	4	8
10	8	**Cornell U**	7,211	7,458	8,269	6,753	5,934	6,293	–3	3
		Total, first 10 institutions	$ 97,890	$ 89,619	$ 89,376	$ 80,883	$ 74,450	$ 70,909	9%	7%
11	9	**Purdue U**	6,893	7,102	7,120	5,978	5,708	5,418	–3	5
12	16	**U of Texas, Austin**	6,723	6,120	6,443	6,405	4,922	4,741	10	7
13	13	**U of Illinois, Urbana**	6,563	6,566	6,193	6,306	5,999	5,371	0	4
14	14	**Pennsylvania State U**	6,429	6,515	5,957	4,915	5,161	5,860	–1	2
15	19	**Princeton U**	6,104	5,681	5,812	5,064	4,575	3,104	7	14
16	21	**U of Wisconsin, Madison**	6,041	5,505	4,939	4,718	5,348	5,156	10	3
17	12	**Rutgers U**	6,016	6,572	3,442	2,525	2,123	2,055	–8	24
18	32	**U of Rochester**	5,998	4,327	3,936	3,275	3,336	2,861	37	16
19	24	**U of Minnesota**	5,857	5,054	4,156	4,395	4,013	2,255	16	21
20	17	**U of Notre Dame**	5,667	5,983	6,557	5,158	4,998	5,097	–5	2
		Total, first 20 institutions	$160,181	$149,044	$143,931	$129,622	$120,663	$112,827	7%	7%
21	11	**Columbia U, main division**	5,540	4,344[b]	4,246[b]	6,625	5,030	4,490	27	4
22	87	**U of Massachusetts**	5,494	1,326	3,296	5,036	4,411	4,091	314	33
23	20	**Northwestern U**	5,465	5,577	4,955	4,641	3,753	3,963	–2	7
24	34	**U of Southern California**	5,358	3,986	3,568	2,903	2,857	2,149	34	20
25	25	**Yale U**	5,256	5,011	5,927	4,909	5,566[b]	5,095[b]	5	1
26	15	**Indiana U**	5,225	6,127	6,354	4,923	4,757	4,885	–15	1
27	22	**U of Colorado**	5,218	5,418	4,603	4,402	4,811	5,430	–4	–1
28	30	**U of Oregon**	5,182	4,435	4,519	3,579	4,345	3,959	17	6
29	26	**Johns Hopkins U**	4,994	4,824	4,830	5,116	4,903	4,155	4	4
30	36	**U of Maryland, College Park**	4,774	3,844	3,793	4,073	3,557	3,323	24	8
		Total, first 30 institutions	$212,687	$193,926	$190,022	$175,829	$164,653	$154,367	10%	7%
31	27	**U of Pittsburgh**	4,721	4,558	4,803	4,028	4,045	3,836	3	4
32	28	**U of North Carolina, Chapel Hill**	4,651	4,534	4,193	3,153	2,929	2,885	3	10
33	39	**U of California, Irvine**	4,437	3,685	4,376	3,386	3,394	3,035	20	8
34	38	**Rockefeller U**	4,331	3,713	3,082	3,247	3,377	2,553	17	11
35	23	**Case Western Reserve U**	4,246	5,161	5,433	5,016	2,062	2,065	–18	16
36	37	**U of Washington**	4,139	3,756	2,904	2,287	1,898	1,738	10	19
37	29	**Ohio State U**	4,085	4,445	5,437	4,517	4,931	3,846	–8	1
38	33	**U of Virginia**	4,038	4,165	3,419	3,281	2,748	2,165	–3	13
39	61	**U of Alabama, Huntsville**	3,880	2,414	1,059	781[b]	463	na	61	na
40	43	**U of California, Santa Barbara**	3,869	3,242	3,196	3,526	3,087	2,709	19	7
		Total, first 40 institutions	$255,084	$229,213	$227,924	$209,051	$193,587	$179,202	11%	7%
41	40	**State U of New York, Stony Brook**	3,816	3,610	3,460	2,930	2,168[b]	2,343	6	10
42	35	**U of Utah**	3,746	3,872	3,614	4,194	4,791	4,426	–3	–3
43	31	**Texas A&M U**	3,716	4,408	4,945	4,019	3,129	4,195	–16	–3
44	44	**Arizona State U**	3,626	3,172	2,813	2,317	2,218	2,306	14	10
45	58	**Emory U**	3,509	2,719	2,362	2,093	2,163	1,184	29	24
46	47	**U of Arizona**	3,210	3,044	2,885	2,499	2,291	1,738	5	13
47	45	**Georgetown U**	3,088	3,113	2,148	2,155	2,252	1,075	–1	23
48	42	**U of California, Davis**	2,996	3,386	2,255	1,980	2,175	1,702	–12	12
49	54	**U of South Carolina**	2,992	2,905	2,839	3,113	3,285	2,787	3	1
50	63	**U of Iowa**	2,929	2,364	1,718	1,846	1,545	1,511	24	14
		Total, first 50 institutions	$288,712	$260,517	$256,963	$236,197	$219,604	$202,469	11%	8%
		NATIONAL TOTAL	$443,402	$421,711	$402,724	$367,765	$338,027	$312,831	5%	7%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Comparing 1990 data with those reported in earlier years may be inappropriate in some areas. Data for 1986 and later were revised in 1989. **a** Imputed. **b** Estimated. **na**=not available. **Source:** National Science Foundation

SCHOOLS SPENDING MOST ON CHEMICAL ENGINEERING R&D: MIT retains lead

Rank 1990	Rank 1989		Chemical engineering: Total spending ($ thousands)	Chemical engineering: Federal funds	Chemical engineering: % federal funds	All engineering: Total spending ($ thousands)	All engineering: Federal funds	All engineering: % federal funds
1	1	**Massachusetts Inst. of Technology**	$ 13,456	$ 9,279	69%	$ 127,004	$ 85,559	67%
2	2	**U of Minnesota**	7,817	5,249	67	27,943	10,781	39
3	3	**U of Texas, Austin**	6,025	2,388	40	58,968	26,031	44
4	8	**Texas A&M U**	6,017	922	15	62,791	13,388	21
5	24	**Georgia Inst. of Technology**	5,382	3,035	56	116,867	65,901	56
6	6	**U of Maryland, College Park**	4,941	1,577	32	43,964	16,336	37
7	5	**Johns Hopkins U**	4,580	4,171	91	204,793	200,964	98
8	11	**North Carolina State U, Raleigh**	4,421	1,764	40	40,181	15,077	37
9	9	**U of Wisconsin, Madison**	4,363	2,407	55	39,781	24,474	61
10	4	**Columbia U, main division**	4,262	2,265	53	17,647	11,777	67
		Total, first 10 institutions	$ 61,264	$33,057	54%	$ 739,939	$ 470,288	64%
11	75	**Oklahoma, State U**	4,028	2,660	66	15,639	6,931	44
12	12	**U of Delaware**	3,826	1,140	30	12,251	4,305	35
13	10	**Case Western Reserve U**	3,665[a]	2,004	55	19,049[a]	12,638	66
14	20	**Auburn U**	3,259	935	29	18,819	5,017	27
15	13	**Stanford U[b]**	3,130	2,701	86	83,694	69,015	82
16	15	**Lehigh U**	3,067	555	18	19,596	7,353	37
17	18	**Princeton U**	2,981	1,281	43	23,048	11,931	52
18	17	**U of Houston**	2,870	1,009	35	8,027	2,754	34
19	30	**Louisiana State U**	2,714	872	22	20,890	8,345	40
20	21	**U of Michigan**	2,668	1,686	63	53,905	31,447	58
		Total, first 20 institutions	$ 93,472	$47,900	51%	$1,014,857	$ 630,024	62%
21	45	**Arizona State U**	2,644	614	23	18,618	4,933	26
22	53	**U of Utah**	2,554	1,120	44	16,502	7,872	48
23	16	**Pennsylvania State U**	2,430	724	30	118,070	74,737	63
24	32	**Virginia Polytechnic Inst. & State U**	2,320	878	38	44,473	22,304	50
25	33	**U of California, Santa Barbara**	2,280	1,764	77	22,214	18,807	85
26	29	**New Mexico Inst. of Mining & Tech.**	2,259	408	18	16,090	2,519	16
27	22	**Cornell U**	2,233	1,340	60	39,663	22,780	57
28	35	**State U of New York, Buffalo**	2,224	1,139	51	23,166	7,900	34
29	28	**U of Washington**	2,133	1,020	48	16,985	11,359	67
30	27	**Rutgers U**	2,133	755	35	21,694	4,262	20
		Total, first 30 institutions	$114,449	$57,662	50%	$1,352,332	$ 807,497	60%
		NATIONAL TOTAL	$206,172	$99,937	48%	$2,681,751	$1,534,931	57%

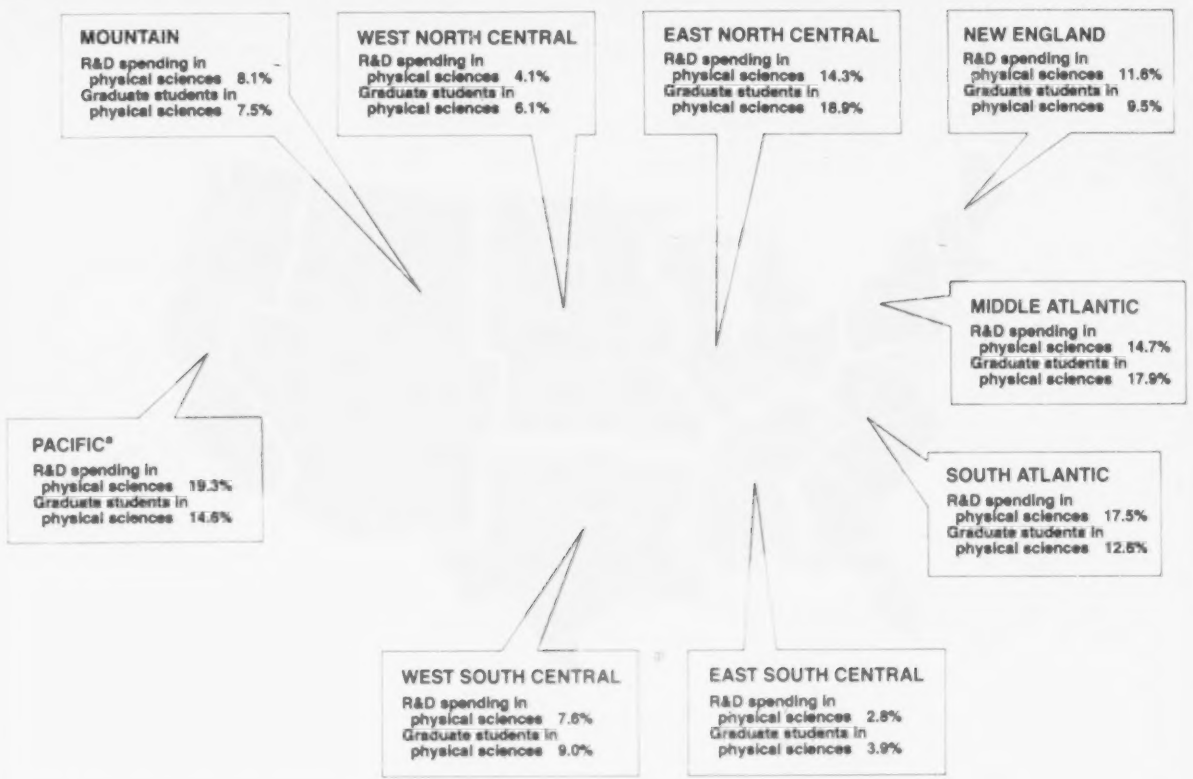
Note: Data for 1990 academic year. a Estimated. b Imputed. **Source:** National Science Foundation

FOREIGN GRADUATE STUDENTS: They now represent more than one fifth of total

	1990		1989		1988		1987[a]		1986[a]		1985[a]		% annual change	
	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	Thousands	% of total	1989–90	1985–95
All sciences	55.9	19%	53.2	19%	51.2	19%	48.2	18%	45.5	17%	41.8	16%	5%	6%
Psychology and social sciences	14.5	11	14.1	12	14.2	12	13.5	12	13.1	12	12.5	11	3	3
Mathematical and computer sciences	13.7	25	13.0	25	12.6	24	12.0	24	11.3	23	10.4	22	5	6
Physical sciences	11.7	34	11.1	33	10.5	32	10.0	31	9.5	29	8.5	27	5	7
Chemistry	6.1	32	5.7	30	5.3	28	4.9	26	4.5	24	4.1	22	7	8
Physics	5.4	39	5.2	38	5.0	38	4.9	37	4.8	39	4.2	36	4	5
Biological sciences	10.8	21	10.1	20	9.1	19	8.1	17	7.2	15	6.4	14	7	11
Biochemistry	1.6	31	1.5	29	1.3	26	1.2	25	1.1	22	1.0	21	7	10
Agricultural sciences	2.7	24	2.6	24	2.6	24	2.6	24	2.5	22	2.3	20	4	3
Earth, atmospheric, and ocean sciences	2.5	18	2.3	17	2.2	16	2.0	4	1.9	13	1.7	11	9	8
Engineering	31.3	29	30.4	29	29.6	28	28.1	27	27.1	26	24.1	25	3	5
Chemical	2.8	42	2.6	40	2.4	36	2.3	32	2.2	31	2.2	31	8	5
Metallurgical and materials	1.8	38	1.8	40	1.6	37	1.6	37	1.5	36	1.3	36	0	7
TOTAL	87.2	22%	83.6	22%	80.8	21%	76.3	20%	72.6	20%	65.9	18%	4%	6%
ANNUAL CHANGE	4%		3%		6%		5%		10%		7%			

Note: The percent of total is the percent of all full-time graduate students in each area who are foreign. a Includes estimated data for master's-granting institutions, which were surveyed on a sample basis from 1984 through 1987. **Source:** National Science Foundation

Schools east of Mississippi River get 61% of R&D funds, 63% of grad students


MOUNTAIN
R&D spending in physical sciences 8.1%
Graduate students in physical sciences 7.5%
WEST NORTH CENTRAL
R&D spending in physical sciences 4.1%
Graduate students in physical sciences 6.1%
EAST NORTH CENTRAL
R&D spending in physical sciences 14.3%
Graduate students in physical sciences 18.9%
NEW ENGLAND
R&D spending in physical sciences 11.6%
Graduate students in physical sciences 9.5%
MIDDLE ATLANTIC
R&D spending in physical sciences 14.7%
Graduate students in physical sciences 17.9%
PACIFIC[a]
R&D spending in physical sciences 19.3%
Graduate students in physical sciences 14.6%
SOUTH ATLANTIC
R&D spending in physical sciences 17.5%
Graduate students in physical sciences 12.6%
WEST SOUTH CENTRAL
R&D spending in physical sciences 7.6%
Graduate students in physical sciences 9.0%
EAST SOUTH CENTRAL
R&D spending in physical sciences 2.8%
Graduate students in physical sciences 3.9%

Key to map: Using the Middle Atlantic states as an example, 14.7% of all R&D expenditures in the physical sciences and 17.9% of all graduate students in physical sciences are in this area. The figures for funding apply to Ph.D.-granting universities and colleges only. The figures for students apply to all universities and colleges.

Note: Data are based on $1.7 billion of R&D expenditures and 34,197 graduate students in the physical sciences enrolled in colleges and universities during the 1990 academic year. a Includes Alaska and Hawaii. **Source:** National Science Foundation

GRADUATE SCIENCE STUDENTS: Modest growth for chemistry, chemical engineering

Thousands	1990	1989	1988	1987[a]	1986[a]	1985[a]	1984[a]	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
All sciences	292.3	281.1	274.4	271.0	267.4	263.8	258.5	257.6	256.1	254.4	265.7	4%	2%
Psychology and social sciences	127.3	120.9	116.2	114.6	112.0	111.9	111.2	113.2	117.1	120.3	130.4	5	–1
Biological sciences	50.9	49.6	48.3	47.5	47.2	46.5	46.2	46.1	46.3	47.0	47.9	3	1
Biochemistry	5.2	5.2	5.0	4.8	4.9	4.7	4.5	4.2	4.1	4.1	4.1	0	5
Mathematical and computer sciences	54.4	52.2	51.9	50.7	49.4	47.5	43.3	41.0	37.0	32.4	28.9	4	7
Physical sciences	34.3	33.6	33.0	32.7	32.3	31.0	30.1	29.5	28.2	28.2	27.0	2	2
Chemistry	19.1	18.8	18.6	18.8	18.7	18.3	17.8	17.8	17.0	16.3	16.2	2	2
Physics	14.0	13.7	13.3	12.8	12.4	11.7	11.3	10.8	10.3	10.2	10.0	2	3
Earth, atmospheric, and ocean sciences	14.2	13.8	14.0	14.5	15.2	15.5	15.6	15.5	15.2	14.4	14.2	3	0
Agricultural sciences	11.2	11.0	11.0	11.0	11.3	11.4	12.1	12.3	12.3	12.1	12.3	2	–1
Engineering	109.3	104.8	103.7	104.6	103.1	97.0	93.6	91.9	84.6	80.5	75.1	4	4
Chemical	6.7	6.5	6.6	7.1	7.0	7.2	7.4	7.6	7.2	6.5	6.0	3	1
Metallurgical and materials	4.8	4.5	4.3	4.3	4.2	3.9	3.7	3.4	3.1	3.1	2.9	7	5
Petroleum	0.7	0.7	0.7	0.8	0.7	0.8	0.7	0.7	0.6	0.5	0.5	0	3
TOTAL	401.6	385.9	378.1	375.6	370.5	360.8	352.1	349.5	340.7	334.9	340.8	4%	2%
ANNUAL CHANGE	4%	2%	1%	1%	3%	2%	1%	3%	2%	–2%	4%		

Note: Data for all institutions. Data for 1981 and later were revised in 1990. a Includes estimated data for master's-granting institutions, which were surveyed on a sample basis from 1984 through 1987. **Source:** National Science Foundation

U.S. Continues To Lead In Global R&D

WORLDWIDE R&D SCIENTISTS AND ENGINEERS: U.S. has more than twice as many as Japan . . .

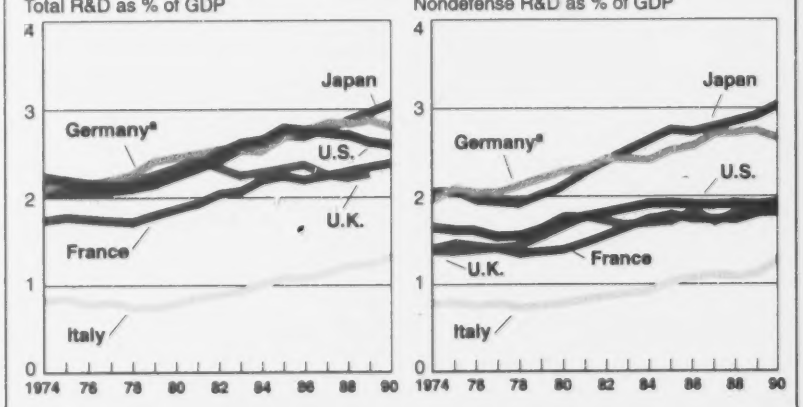
Thousands	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	% annual change[a] 1979–89	% annual change[a] 1988–89
U.S.	na	949	927	910	882	841	798	752	712	683	651	615	2%	4%
Japan[b]	482	462	442	418	406	381	370	342	330	318	303	282	4	5
Germany[c]	na	176	na	166	na	144	na	131	na	125	121	117	na	4
France[d]	na	121	115	109	105	102	98	93	90	86	75	73	5	5
U.K.[e]	na	na	103	101	102	98	na	94	na	95	na	na	na	na
Italy	na	76	75	71	68	64	62	63	57	52	47	46	1	5

. . . but barely leads Japan in proportion in labor pool

Per 10,000 labor force	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	% annual change[a] 1979–89	% annual change[a] 1988–89
U.S.	na	75.6	75.2	74.9	73.8	71.8	69.2	66.4	63.6	61.9	60.0	57.7	1%	3%
Japan[b]	75.6	73.6	71.7	68.8	67.4	63.9	62.4	58.1	57.1	55.6	53.6	50.4	3	4
Germany[c]	na	59.3	na	56.4	na	49.7	na	45.7	na	44.0	43.2	42.5	na	3
France[d]	na	49.7	47.6	45.4	43.7	42.8	41.1	39.1	37.9	36.3	32.1	31.4	4	5
U.K.[e]	na	na	36.3	36.2	36.6	35.3	na	35.3	na	35.7	na	na	na	na
Italy	na	31.4	30.9	29.4	28.4	27.1	26.6	27.3	24.9	22.9	20.8	20.8	2	4

Note: Table represents all scientists and engineers engaged in R&D on a full-time equivalent basis. **a** Annual change for Japan calculated for 1989–90 and 1980–90. **b** R&D scientists and engineers employed primarily in natural sciences and engineering. **c** Data are for former West Germany. **d** Figures increased in 1981 in part because of reevaluation of university research efforts. **e** Data comprise government and industry sectors only. **na**=not available. **Source:** National Science Foundation

U.S. share of GDP spent on R&D drops further behind Japan and Germany when only nondefense R&D is considered



Note: GDP = gross domestic product. **a** Data are for former West Germany. **Source:** National Science Foundation

TOTAL AND NONDEFENSE R&D: Italy's and Japan's R&D spending growing fastest

$ Billions, constant 1987	1990	1989	1988	1987	1986	1985	1984	1983	1982	1981	1980	% annual change 1989–90	% annual change 1980–90
TOTAL R&D													
U.S.	$129.5	$129.8	$128.8	$125.4	$123.3	$120.6	$111.1	$102.3	$95.5	$91.1	$87.3	0%	4%
Japan	59.2	54.5	50.3	46.9	43.9	43.5	39.6	37.1	34.5	32.0	29.3	9	7
Germany[a]	28.8	28.2	27.2	26.5	24.9	24.4	22.4	22.0	21.8	21.1	21.4	2	3
France	20.9	19.9	18.8	18.1	17.5	17.3	16.8	16.0	15.6	14.6	13.3	5	5
U.K.	na	18.0	17.4	16.9	16.8	15.9	na	15.0	na	15.4	na	na	na
Italy	11.1	10.0	9.5	9.0	8.3	8.1	7.1	6.6	6.2	6.0	5.1	11	7
Sweden	na	3.6	na	3.7	na	3.4	na	2.9	na	2.5	na	na	na
NONDEFENSE R&D													
U.S.	$ 94.1	$ 92.3	$ 90.2	$ 86.2	$ 85.2	$ 84.9	$ 78.9	$ 73.7	$69.2	$67.8	$66.5	2%	4%
Japan	58.8	54.1	49.9	46.6	43.6	43.2	39.3	36.9	34.3	31.9	29.1	9	7
Germany[a]	27.3	26.9	26.0	25.2	23.6	23.2	21.4	21.0	20.9	20.2	20.4	1	3
France	16.0	15.6	14.6	14.2	13.7	13.7	13.3	12.6	12.0	10.9	10.3	3	5
U.K.	na	14.7	14.1	13.3	13.0	11.8	na	11.1	na	11.4	na	na	na
Italy	10.7	9.4	8.9	8.6	7.9	7.6	6.7	6.4	6.1	5.8	5.1	14	8
Sweden	na	3.2	na	3.3	na	3.0	na	2.6	na	2.3	na	na	na

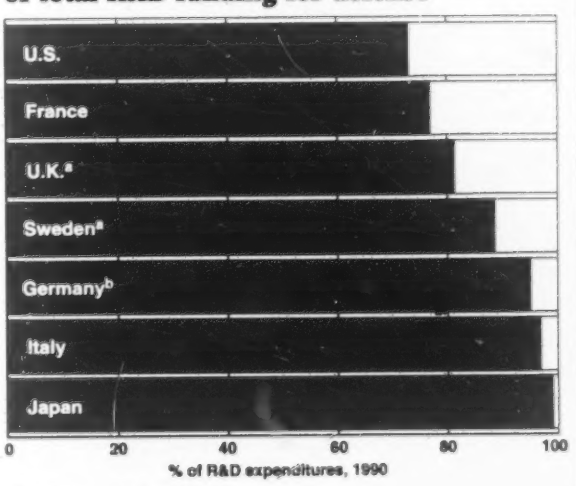
Notes: Foreign currency conversions to U.S. dollars are calculated based on Organization for Economic Cooperation & Development purchasing power parity exchange rates. a Data are for former West Germany. **na** = not available. **Source:** National Science Foundation

ORIGIN OF CHEMICAL LITERATURE: U.S. dominates, increasing its share to nearly 30%

% of total[a]	1991	1987	1983	1979	1975
U.S.	29.2%	27.8%	27.0%	27.5%	25.8%
Japan	12.5	11.7	10.6	9.7	7.3
U.S.S.R.	11.1	12.7	17.0	19.0	24.6
Germany[b]	7.3	7.2	7.3	7.2	6.8
U.K.	5.7	5.7	5.8	5.9	6.3
France	4.2	4.2	4.1	4.2	4.1
China	4.0	3.3	2.1	0.3	0.1
Canada	3.0	3.0	2.7	2.9	2.7
India	2.7	3.0	3.0	3.1	2.7
Italy	2.4	2.3	2.5	2.2	2.1
Poland	1.5	1.7	1.8	2.2	2.1
Netherlands	1.5	1.4	1.4	1.3	1.1
Spain	1.4	1.4	0.9	0.7	0.5
Australia	1.2	1.3	1.3	1.2	1.1
Sweden	1.1	1.2	1.1	1.1	1.2
Switzerland	1.1	1.1	1.0	1.0	1.0
Czechoslovakia	0.8	1.2	1.1	1.4	1.6
All others	9.3	9.8	9.3	9.1	8.9
TOTAL PAPERS (THOUSANDS)	453.6	386.5	371.4	370.8	317.5

a Source of journal literature abstracted in *Chemical Abstracts* based on author's address. b Figures for years prior to 1991 are combined total for West Germany and East Germany. **Source:** Chemical Abstracts Service

U.S. and France each spend about a fourth of total R&D funding for defense



a Data are for 1989. b Data are for former West Germany. **Source:** National Science Foundation